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The Effect of Length on the Properties of Reinforced Concrete Columns

Theoretical and Applied Mechanics

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THE EFFECT OF LENGTH ON THE PROPERTIES OF REINFORCED CONCRETE COLUMNS

BY

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY ANDREW JOHN ALBERT ANDERSON

ENTITLED The Effect of Length on the Properties of Reinforced Concrete Columns.

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science in Theoretical and Applied Mechanics

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....	Final Examination*

*Required for doctor's degree but not for master's.

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I. INTRODUCTION.

1. Preliminary: The subject of reinforced concrete columns was first investigated from a scientific standpoint by A. Considere, in France. To him is attributed the idea of enclosing a concrete column with a steel spiral to add to its strength. In the last ten years a great many tests have been made to determine the correct basis for the design of reinforced concrete structures, and much valuable information has accumulated. With respect to columns, most of the tests have been made with one of the two following types of reinforcement,- either spiral reinforcement or longitudinal reinforcement. The effect of varying the percentage of either type of reinforcement and keeping the other constant, together with their effectiveness when used in columns of varying length, has not been so fully investigated.

The series of tests undertaken in this thesis was planned to throw light upon the effectiveness of various combinations of spiral and longitudinal reinforcement in columns of various lengths. It is hoped that the results will be helpful in discussing the fundamental principles of the design of reinforced concrete columns.

2. Scope of Investigation: This series of tests was planned in connection with another series which was similar in character except that eccentric load was applied in place of concentric load. The columns in the two series of tests were alike except that eccentric load was applied to only two lengths, namely, 5ft. and 10ft. This similarity in makeup of the columns permitted a direct comparison between the two to be made to show the effect of eccentricity and length.

The series of tests described in this thesis was planned to show the effect of length. It was composed of

thirty-six columns. Four different lengths were used; namely 5ft. 10ft., 15ft., and 20ft. Two percentages of spiral reinforcement, as well as two percentages of longitudinal reinforcement were used. With this division of the variables, there were three columns that were identical with respect to length and percentages of spiral and longitudinal reinforcement.

3. Acknowledgement: This series of tests was made at the Laboratory of Applied Mechanics of the University of Illinois. Special acknowledgement is made to Professor A.N.Talbot, Professor in charge of Theoretical and Applied Mechanics, University of Illinois, for his general supervision, advice and valuable suggestions both in making the tests and interpreting the results. The fabrication of the columns was directly supervised by Mr.H.F.Gonnerman, First Assistant in the Engineering Experiment Station. Much of the success of this thesis is due to Mr.J.O.Draffin, Research Fellow in the Engineering Experiment Station, for his hearty cooperation in the planning, testing and reduction of data in this thesis. Messers L.J.Larson and R.L.Templin, Research Fellows in the Engineering Experiment Station assisted in the testing.

4. Theoretical Discussion: **There are three factors in the reinforced concrete columns of this series, in addition to the plain concrete, that may be treated mathematically with more or less exactitude. These are the action of the longitudinal reinforcement, of the spiral reinforcement and the effect of length. In the consideration of these factors each will be discussed separately as well as their effect upon each other.**

The simplest case which can occur is that of a very short column of homogeneous material, and one in which no bending

occurs. The expression for the total load carried by a column of this type is $P=pA$.

When the column is of such a length that flexure may enter into the failure, this simple formula will no longer apply and another must be used in which the effect of the stiffness of the material, length, and diameter of the column must be taken into consideration. The formula that is most widely known, and which is based upon theoretical considerations, is known as Euler's Formula. The derivation of this formula is given in all standard textbooks on Mechanics. In its general form it is,

$$P'=\frac{r^2\pi^2EI}{l^2}$$

in which P' is the load at which bending commences, and r is a constant depending upon the condition of fixity of the ends.

In the preceding discussion the assumption has been made that the material was homogeneous. This condition, however, is not true for a reinforced concrete column. It will therefore be necessary to consider the strength contributed by the different elements.

The expression for the total strength of a reinforced concrete column may therefore be written as,

$$P=P_c+P_l+P_s \text{-------------------------------------} (1)$$

in which P is the total load carried by the column: P_c, that portion carried by the concrete: P_l, that carried by the longitudinal reinforcement: and P_s, that due to the action of the spiral. In the derivation of the expressions for the above quantities the following notation will be used:

P = applied load.

p = unit load on column.

d = diameter of column, center to center of spiral.

A = area of column = $\frac{\pi d^2}{4}$

A_s = total area of longitudinal reinforcement.

A_c = net area of concrete = $\frac{\pi d^2}{4} - A_s$

p_l = percentage of longitudinal reinforcement.

p_s = percentage of spiral reinforcement.

a = area of cross-section of equivalent thin cylinder.

t = thickness of equivalent thin cylinder.

E_s = modulus of elasticity of steel.

E_c = modulus of elasticity of concrete.

$n = E_s/E_c$

μ = Poisson's ratio for concrete.

ε_c = unit vertical deformation in the concrete when unrestrained laterally.

ε_c^{I} = net vertical deformation of the concrete.

ε_c^{II} = unit lateral deformation of the concrete when unrestrained laterally.

ε_c^{III} = unit lateral deformation in the concrete when subject to a lateral restraint in two directions at right angles to each other.

ε_c^{IV} = net lateral deformation of the concrete,

ε_l = unit deformation of the longitudinal reinforcement.

ε_s = unit deformation of the spiral reinforcement.

f_c = unit vertical stress in the concrete caused by a deformation of ε_c^{III}.

f_s = unit stress in the spiral caused by a deformation of ε_s.

The portion carried by the concrete is,

$$P_c = pA_c = pA(1-p_l) \text{ ------------------------(2)}$$

Portion carried by the longitudinal reinforcement: The total cross-sectional area of the longitudinal reinforcement, expressed as an equivalent concrete area is,

$$np_1A$$

Therefore the portion of the load carried by the longitudinal reinforcement is,

$$P_1 = pnp_1A$$

The portion carried by the spiral reinforcement: When a load is applied to a plain concrete column there is a lateral deformation proportional to the applied load. If the column is reinforced by a spiral so as to reduce the amount of this lateral deformation there will be an increase in the strength of the column over that of a plain one. The amount of this increase in strength is represented by,

$$f'_c = f_c\left[1+\frac{np_s\mu}{np_s(1-2\mu)+2}\right]^*$$

This formula is generally accepted as representing the action of the spiral reinforcement in a concrete column but it is based upon the assumption that the failure of a column is due to shear. It does not take into account the fact that while the shear may be zero there may still be a deformation in the concrete. There is a possibility that this deformation may cause failure, even though the shear be very small.

The following formula has been derived in which no assumption in regard to shear has been made. It is based entirely upon the deformations of the concrete.

Assuming the spiral to be replaced by a cylinder, the percentage of reinforcement remaining the same, we have,

$$a = p_s\frac{\pi d^2}{4} = p_s\pi r^2,$$

---

* Johnson's Materials of Construction.

$$t = p_s \frac{\pi r^2}{2\pi r} = p_s \frac{r}{2}$$

The total stress in the cylinder per unit of length is,

$$2f_s t = f_s p_s r$$

This stress in the cylinder will cause a stress in the concrete. Let f denote this unit stress. Then,

$$f_s p_s r = 2rf$$

$$f = \frac{f_s p_s}{2}$$

But $f = E_c \varepsilon_c^{III}$, also $\varepsilon_c^{II} = \frac{f_s p_s}{2E_c}$ ------------ --------------(4)

The deformation ε_c^{III} is that due to the stress f: ε_c^{II} is the deformation which would take place if the restraining force f_s were removed.

Therefore, $\varepsilon_c^{III} = \varepsilon_c^{II}$

As the spiral exerts a lateral pressure on the concrete in two directions at right angles to each other, ε_c^{III} in (4) becomes,

$$\varepsilon_c^{III} = \frac{f_s p_s}{2E_c}(1-\mu) \qquad \text{-------------------------------(5)}$$

The unit lateral deformation of the unrestrained column due to the load p would be $\mu\varepsilon_c$. But the pressure due to the stress in the spiral reinforcement caused a deformation of ε_c^{III}. This is opposite in direction to $\mu\varepsilon_c$ and therefore the resulting unit lateral deformation is,

$$\varepsilon_c^{IV} = \mu\varepsilon_c - \varepsilon_c^{III} = \mu\varepsilon_c - \frac{f_s p_s}{2E_c}(1-\mu) \qquad \text{-----------------(6)}$$

Assuming that there is no failure of bond between the concrete and the spiral, the unit deformation of the spiral will equal the unit deformation of the concrete. The unit deformation of the spiral is,

$$\frac{f_s}{E_s} = \frac{f_s}{nE_c}$$

Therefore, $\frac{f_s}{nE_c} = \varepsilon_c^{IV} = \mu\varepsilon_c - \frac{f_s p_s}{2E_c}(1-\mu)$ ------------------(6a)

The vertical deformation of the concrete, when unrestrained laterally, due to the load *p* is ε_c. If restrained laterally, the vertical deformation due to this restraint is $2\mu\varepsilon_c^{III}$. Therefore the resulting unit vertical deformation due to the load *p* is,

$$\varepsilon_c' = \varepsilon_c - 2\mu\varepsilon_c^{III}$$

Substituting the value of ε_c^{III} from (5) we have,

$$\varepsilon_c' = \varepsilon_c - 2\mu\frac{f_s p_s}{2E_c}(1-\mu) \quad \text{------------------------(7)}$$

Since

$$\varepsilon_c = \frac{S}{E_c} \quad \text{and} \quad \frac{f_s}{E_c} = \frac{2n\mu\varepsilon_c}{2 + p_s n(1-\mu)} \quad \text{from (6a)}$$

we have by substitution in (7)

$$\varepsilon_c' = \frac{S}{E_c} - 2\mu\frac{p_s}{2}\;\frac{2nS\mu}{2+p_s n(1-\mu)E_c}\;(1-\mu)$$

Let $\quad \varepsilon_c' = \frac{S'}{E_c}$

Then $\quad S' = S - 2\mu\left[\frac{p_s nS\mu(1-\mu)}{2+p_s n(1-\mu)}\right]$

Clearing of fractions and reducing we have,

$$S' = S\left[1 - \frac{2p_s n\mu^2(1-\mu)}{2+p_s n(1-\mu)}\right] \quad \text{-------------------(8)}$$

If we assume that the stress in the column is expressed by $\varepsilon_c E_c$, then S' is the stress in a spirally reinforced column due to a load *P* which in a plain column causes a stress of S. This is the change due to the spiral, therefore we may write for the strength of a spirally reinforced column,

$$P' = P_c\left[1 + \frac{2p_s n\mu^2(1-\mu)}{2+p_s n(1-\mu)}\right] \quad \text{-----------------(9)}$$

The additional strength due to the action of the spiral is,

$$P_s = P_c \left[\frac{2p_s n \mu^2 (1-\mu)}{2+p_s n(1-\mu)} \right] \text{------------------------}(10)$$

Substituting the derived values for P_c, P_1, and P_s in (1) we have,

$$P=pA(1-p_1)+pnp_1A+p\,\frac{2p_s n \mu^2(1-\mu)}{2+p_s n(1-\mu)} \qquad \text{or}$$

$$P = p\left[A\,(1-p_1+np_1) + \frac{2p_s n \mu^2(1-\mu)}{2+p_s n(1-\mu)}\right] \text{-----------}(11)$$

This formula does not consider the effect of length. If reference is made to the curves on page 245 it will be seen that the term which would represent the effect of length would change with each combination of reinforcement used in the tests. For this reason no general term has been derived to account for the effect of length upon the strength of reinforced concrete columns. It should be noted that the increase in strength due to the spiral reinforcement as found by the above formula is much less than the amount obtained in tests of spirally reinforced columns.

II. MATERIALS, SPECIMENS,
and
METHOD OF TESTING.

1. **Materials**: The materials used in making the concrete for this series of tests were bought in the open market. They are the same as have been used by the Engineering Experiment Station for a number of years.

Gravel: The gravel came from Attica, Ind. It was washed and ordered to pass a 1-in. screen. It was composed of silicious material largely quartz, and the pebbles were smooth, hard and fairly brittle. It was well graded as is shown by Table I, page 9 , which gives a mechanical analysis of the gravel.

TABLE I.

Mechanical Analysis of Gravel.

Each value is the average of four tests.

Size of Sq. Opening	Separation Size—in.	Percent Passing Sieve.
1.050	——	100.0
0.742	——	83.7
0.525	——	49.5
0.371	——	19.3
No. 3	0.263	7.0
No. ~~5~~ 4	0.185	3.5
No. 8	0.093	1.6

Sand: The sand was a clean, coarse, well graded torpedo sand, obtained near Attica, Ind. Table II gives the mechanical analysis of four samples.

TABLE II

Mechanical Analysis of Sand.

Sieve No.	Separation Size—in.	Percent Passing Sieve.
3	0.263	97.1
5	0.185	86.4
6	0.131	69.4
8	0.093	58.4
14	0.046	36.2
28	0.0232	19.2
48	0.0116	4.2
100	0.0058	1.1
150	0.0041	0.7

Cement: Universal Portland Cement was used in this series of tests It fulfilled the requirements of the specifications of the American Society of Civil Engineers. Table III gives the tensile strength of neat and 1-3 mortar briquettes.

TABLE III

Tensile Strength of Cement.

Ref. No.	Ultimate Strength— lbs. per sq. in.			
	Neat		1-3 Mortar	
	7 days	28 days	7 days	28 days
1	636	695	220	312
2	616	684	246	290
3	606	716	236	299
4	519	683	242	279
Av.	594	694	236	295

Steel: Tension Test Pieces: Four 4-ft. coupons were furnished for each size of spiral wire. These were cut into test pieces 16 in. long, making twelve test pieces for each size of spiral wire. Nine of these were tested. The three remaining were saved for future reference in case additional data were necessary. The nine pieces were tested in a 50,000 lb. Riehle testing machine. A Ewing extensometer with an 8-in. gage length was used to measure the unit deformation up to 0.006 in. which corresponds to a unit stress of about 45,000 lbs. Loads were read for equal increments of deformation. After the steel had reached a unit deformation of 0.006 in., the extensometer was removed and an 8-in. vernier extensometer reading directly to 0.01 in. was fastened on the specimen, and the deformations were read up to the ultimate load. The elongation in eight inches, yield point and reduction of area was noted for each specimen. The individual curves can be found on pages 59 to 64.

Test specimens were cut from the rods which were used as

longitudinal reinforcement. A Ewing extensometer with an 8-in. gage length was used to measure the unit deformations up to about 0.006in. and 0.003 in. for the 1-in. and 5/8-in. rods respectively. These deformations correspond to unit stresses of about 45,000lbs. and 35,000lbs. respectively. Shortly after the yield point had been reached, the extensometer was removed and the deformations were measured over an 8-in. gage length by means of a pair of calipers and a scale. The individual curves can be found on pages 51 to 58.

Johnson's method was used in determining the yield point of the steel. Table IV contains all the data for the tension tests of steel.

Steel, Compression Test Pieces: Seven specimens, each 2.5 in. long, were cut from each of the sizes of rods used as longitudinal reinforcement. The ends were squared in a lathe to insure a uniform bearing and parallel surfaces. The specimens were tested in a 100,000 lb. Riehle testing machine. A Ewing extensometer with a gage length of 1.25 in. was used to measure the unit deformations up to about 0.015 in. Loads were read at equal increments of deformation. After the steel had reached a unit deformation of about 0.015 in. the extensometer was removed and the deformations were measured by noting the distances between the bearing surfaces of the machine. The constant of the extensometer was later found to be incorrect making the modulus too low. The modulus of elasticity in compression has therefore been assumed to be 30,000,000. For this reason the curves have not been shown.

Table V contains all the data for the compression tests of steel.

TABLE IV.

Tension Tests of Reinforcement.

Diam. Bar in.	Kind of Reinforcement.	Elas. Limit. lb. per sq. in.	Ave. variation. %	Ultimate Strength lb. per sq. in.	Ave. variation. %	Modulus of Elasticity	Ave. variation. %	Unit Elongation in 8 in.	Reduction in Area %
1/4	Spiral	38,200	6.54	68,500	2.50	29,340,000	4.77	18.06	55.90
3/8	Spiral	36,200	2.95	65,200	3.05	29,070,000	4.39	18.10	61.50
5/8	Long.	36,200	5.20	54,600	3.06	29,510,000	1.23	27.16	66.00
1	Long.	41,500	4.53	67,600	8.38	29,640,000	2.47	28.41	56.25

TABLE V.

Compression Tests of Longitudinal Steel.

Diam. Bar in.	Elas. Limit. lb. per sq. in.	Average variation %	Ultimate Strength lb. per sq. in.	Average variation %
5/8	38,800	3.53	93,250	6.55
1	38,600	1.66	127,280	0.17

2. Specimens: All of the columns were approximately 12in. in diameter center to center of spiral. They were made in four lengths, namely 5ft.,10ft., 15ft., and 20ft.

The spiral reinforcement was of two sizes, namely 0,25in. and 0,375in. in diameter. The pitch was 1.5in. for both sizes of spiral and was as uniform as is possible to obtain. The last four turns of the spiral were tied together in pairs about 1.5in. apart. The ends of the spiral were bent inward to provide for anchorage. Each spiral was held in position by three spacing bars which consisted of 0.75in. 0.41b. channels, placed 120° apart. These bars were twisted slightly in a longitudinal direction owing to the slight uncoiling of the spiral.

The longitudinal reinforcement consisted of 5/8in. and 1in. round rods, cut to the exact length of the form. Eight longitudinal rods were used in each column. The ends were carefully squared to provide an even bearing. These rods were spaced equidistant around the inner circumference of the spiral and wired securely to it.

3. Forms: The forms were made from a standard 12in. steel pipe cut longitudinally into four sections. In order that the columns might be perfectly straight, the forms were made as long as the column for which they were to be used. Small wooden strips were inserted between the sections of the form in order to secure a snug fit around the spiral and adjust it to any slight difference in the diameter thereof. After the reinforcement had been placed in the form, steel bands were placed around the form about 2ft. apart and tightened securely. This type of form was found to be rigid and to give a perfectly straight column, a condition that was almost impossible to obtain when the forms were in sections.

4. Fabrication: All of the work of making the specimens was done under the supervision of Mr. H.F.Gonnerman in the Concrete Laboratory of the University of Illinois, by men who have done this work for a number of years.

The spiral was placed in a horizontal position and the longitudinal rods, which had been previously cut to the exact length with special attention to having the ends square, were placed inside the spiral. The longitudinal rods were equally spaced around the circumference and then wired to the spiral at* frequent intervals. In order that these rods might be parallel to the longitudinal element of the column, they were lined up by placing the spiral in one of the sections of the form and using the edges thereof as a guide. The photograph on page 299 shows the spiral about to be placed in the form. After the longitudinal rods had been properly placed in and wired to the spiral, the form was oiled, placed around the spiral and tightly clamped. The form was then placed in an upright position on an oiled cast iron base plate and fastened securely.

The concrete was a 1:2:4 mixture proportioned by loose volume and checked by weight. It was machine mixed and after mixing was deposited on the cement floor where it was turned once by shovels. It was then hoisted to the top and emptied into the form. The concrete was sufficiently wet to flow around the spiral fairly well, but was kept thoroughly agitated by means of a long tamping rod in order to prevent any voids around the spiral and also to work out the entrained air. The results obtained in both of these directions were highly satisfactory as indicated by the absence of voids and the density and compactness of the concrete.

After the concrete had been allowed to settle for a few hours, the columns were capped with a neat cement mortar and covered with a cast iron plate. It should be noted that the longitudinal rods bore directly against the upper and lower plates.

Two 8in. by 16in. cylinders were made from the same batch of concrete used in making the column. One was made at the start and the other at the end of the pouring of the column. After the concrete in these cylinders had settled a few hours they were capped with a neat cement mortar and covered with a glass plate.

5. Storage: The columns were left in the position in which they were made until they were to be tested. Two days after pouring the forms were removed and a burlap housing was spread over and around the columns. This burlap was sprinkled daily which kept the atmosphere underneath sufficiently damp to permit the columns to cure uniformly over their entire length and at a fairly regular rate. The columns were removed from this housing a week to 10 days before time for testing to allow them to dry out thoroughly.

The control cylinders were removed from the forms at the end of 2 days and stored in damp sand. These were removed from the sand about a week before the time for testing to allow them to dry out thoroughly.

6. Preparation of the Specimen: Each column was made upon a cast iron base plate having four holes 90° apart and capped with a similar plate. When the column was to be transported from the concrete laboratory to the testing laboratory, an eyebolt was screwed into each of the holes in the base plate; rods were then

hooked through the eyebolts and passed through the holes in the upper plate where they were held by nuts. These nuts were screwed down firmly and the rodded column was loaded on a wagon by means of a crane and transported to the testing laboratory. This was done two or three days before a column was due to be tested.

For gage lines on the steel,holes were drilled directly in the steel after the concrete that covered it had been chipped away. For gage lines on the concrete, holes were drilled in the concrete and steel plugs, one-half inch in diameter and three-quarters of an inch long, were inserted and held in place by means of gypsum plaster. A 10in. gage length was used for all longitudinal deformations, and a 4in. gage length for all lateral deformations. The location of the gage lines is shown by the drawings on page 295 to 298.

7. Apparatus: All of the columns were tested in a 600,000 lb. Riehle testing machine. The deformations were measured by means of an Illinois type of the Berry extensometer. A piece of Invar steel set in a block of wood was used as a standard bar for a part of the tests. This was later substituted by a piece of mild steel incased in gypsum plaster. This rod was exposed at the ends and at the gage points.

The total deformation was measured by fastening a fine wire to a bolt which was placed in a hole drilled in the concrete and held in place by means of gypsum plaster, about 5in. from the bottom of the column. This wire was passed around the spindle of a Weissler dial held in place by the same method, a similar distance from the top of the column, as the bolt. A small weight fastened to the loose end of the wire kept it taut

and caused the total deformations to be registered on the dial. The bending was measured at the center of the columns on a pair of mirrors placed at right angles to each other, each carrying a scale reading to fiftieths of an inch. The readings in each direction were noted by lining in the chord with its image.

The control cylinders were tested in a 200,000 lb. Olsen testing machine. The deformations were measured over a gage length of 10 in. by a special instrument equipped with a Wissler dial reading unit deformations directly.

8. Testing: The columns were placed in the testing machine and the upper end was carefully centered. The rods were then removed and the top of the column examined to determine whether a gypsum plaster cap was necessary to insure a uniform distribution of the load. The head of the machine was run down until the spherical bearing block rested on the upper plate. The block was then centered on the column to insure axial loading.

Zero readings were taken with no load at all on the column or only that of the spherical bearing block. A load ranging from 20,000 lbs. to 50,000 lbs. was applied and the bearing block was fixed by means of angle blocks and wedges. This made the column fixed ended. These blocks and wedges can be seen in position in the photograph on page 304.

The load was applied with the speed of the head of the testing machine of 0.05 in. per minute in all tests.

III. EXPERIMENTAL DATA
and
DISCUSSION.

1. Explanation of Tables: Tables I and II give the results of mechanical analyses of the gravel and sand used in these tests. In Table III are given the results of tension tests of neat cement and 1-3 cement mortar briquettes at the ages of 7 days and 28 days. Table IV gives the results of tension tests of steel used as spiral and longitudinal reinforcement. Table V gives the results of compression tests of steel used as longitudinal reinforcement.

Table VI gives the load in lbs. per sq. in., the longitudinal deformation, Poisson's ratio and the higest stress developed in the spiral for each column as well as the average values for the same at various stresses in the spiral. The values were obtained from the general average curves shown on pages 208 to 244.

Table VII gives the values of the modulus of elasticity of the columns, the modulus of elasticity of the concrete of the columns, values of n and a ratio between the moduli of elasticity of the control cylinders and the concrete of the columns.

Table VIII gives a record of the various dimensions and properties for all of the columns. It gives the dates on which the columns were made and tested, the results of the control cylinders the unit load required to produce a unit deformation of 0.001 in. in the spiral and the value of Poisson's ratio at this load, also some other items of general interest.

2. Explanation of Curves: On pages 245 to 254 are given curves showing general results obtained by plotting the average values given in Tables VI, VII and VIII. These curves are discussed later. The title on each page of curves covers all details and further explanation is deemed unnecessary. On pages 51 to 64 are given the stress deformation curves for steel used as spiral and longitudinal reinforcement. The load deformation curves for the control

cylinders are shown on pages 65 to 78. The corresponding column number is given in each case. The number in a circle refers to the number of the cylinder as two were made for each column and in some cases the deformations were taken on both. One cylinder was made at the start of the pouring and the other at the end. The average load deformation curves for each level at which readings were taken are shown on pages 79 to 137. The average of all of the gage lines at any one level in a certain direction on one or the other of the materials is plotted here. The general average curves for each column are shown on pages 208to 244. Here the average of all of the readings in a certain direction on one or the other of the materials for each load is plotted. The distribution curves are shown on pages 138 to 207. The values plotted are the same as those plotted in the average load deformation curves. These curves show the variation in deformation along the length of the columns.

3. Explanation of Drawings: On pages 295 to 298 are drawings showing the location of the gage lines for each length of column tested as well as the numbering system used in referring to them. The developed surface of the column is shown in each case.

4. Explanation of Photographs: On pages 299 to 305 are given photographs which show some of the most characteristic features of the tests. A detailed description is given under each photograph.

5. Phenomena of Tests; This section contains the notes regarding the behavior of each column during the test. The word "scaling" refers to that of the longitudinal steel only. The word "deflection" means the deflection at the center of the column. The top of the column was centered in the machine and measurements were taken at the bottom to determine whether the column was plumb. In some instances while straight they were not plumb. The wedges were set at loads varying from 20,000 lbs. to 50,000 lbs.

8986-1

At 226,000 lbs. crushing of the concrete over the spiral at the top began. Scaling at gage lines 201 and 241 occurred at 234,000 lbs. Slight spalling at center at 350,000 lb. At 352,000 lbs. the crushing of the concrete over the spiral had become general. Spalling increased materially over the central portion at 424,000 lbs. At 445,000 lbs., (Maximum Load) spiral broke at gage line 45. The outer shell had spalled off except for about one foot at each end.

8986-2

At 204,400 lbs. scaling was noted at gage line 241. Scaling occurred at gage lines 221 and 247 at 221,000 lbs. At 268,000lbs. short vertical cracks over the longitudinal rods were noted. The column was deforming rapidly at this load as indicated by the action of the machine. General crushing of the concrete at the bottom began at 307,000 lbs. At 343,000 lbs. spalling all around on the lower half. At 370,000 lbs. spalling on north and north-west sides at the top began. At 385,000 lbs. spalling was general all around except for upper $1\frac{1}{2}$ ft. where

the surface was only slightly cracked. At 395,000 lbs. all of the concrete was spalled off in central portion on north side. At a load of 420,000 lbs. spalling indicated a bending toward the north-east. At 423,200 lbs. (Maximum Load) there was a deflection of one-quarter in. to the north and east.

8986-3

At 203,000 lbs. slight crushing of concrete at top over spiral. At 261,000 lbs. scaling at gage lines 245 and 223. A load of 290,000 lbs. was applied but the clutch did not work and load was released to 280,000 lbs. and was again brought up to 290,000 lbs. Spalling over spiral at the top began at 369,000 lbs. on east and south sides also on west side at the bottom. This became general at 372,000 lbs. At 453,300 lbs. (Maximum Load) all of the concrete in the central portion was spalled off, but failure was general as shown by all of the gage lines on the spiral going beyond the limit of the instrument. A considerable portion of the concrete shell remained in tact at the top and bottom of the column.

8988-1

At 411,000 lbs. short vertical crack over longitudinal rod at the top on south-west side. Scaling was noted at a number of places. At 469,000 lbs. slight crushing of concrete over spiral at bottom. Spalling began at 528,000 lbs. at the bottom. At 585,000 lbs. general crushing of concrete at the center. At 600,000 lbs. the indications were that the column would take 25,000lbs. or 30,000 lbs. more. Spalling was rather general but only in small amounts. A very thin layer of concrete underneath the lower end of the longitudinal rods appeared to have been crushed.

8988-2

At 404,000 lbs. scaling occurred at gage lines 243, 245 and 225. At 434,500 lbs. scaling was noted at all gage lines at the bottom and center. No crushing of concrete appeared at this load. At 462,000 lbs. slight crushing at the bottom on the south-east side. At 491,000 lbs. slight crushing of the concrete at the top all around the column. At 630,000 lbs. crushing became appreciable at the center. The concrete at the top appeared to be of a better quality than that at the bottom. This column exceeded the capacity of the machine.

8988-3

At 358,000 lbs. slight crushing over spiral at top. At 395,000 lbs. scaling occurred at gage lines 207 and 201. At 439,000 lbs. crushing began at center all around. Spalling commenced at 485,000 lbs. at the center. At 560,000 lbs. the concrete was spalling badly at the center. Maximum load was 572,000 lbs. At this load the spiral broke at gage line 1 and the load fell to 555,000 lbs. directly thereafter.

8989-1

At 440,000 lbs. slight crushing 10" from top on N.-E. side, also at center on same side. Scaling at all gage lines. At 472,000 lbs. slight crushing rather general. Small vertical cracks appeared over the longitudinal rods at top and bottom. At 550,000 lbs. the outer shell was generally cracked with slight spalling at the top. At 615,000 lbs. the surface of the lower half was badly crushed but no spalling occurred. Spalling was quite general over the upper half. This column exceeded the capacity of the machine.

8989-2

No scaling was noted at 413,000 lbs. At 440,000 lbs. scaling on all gage lines at lower level and all gage lines at the center except 227. Scaling at 205 also. No crushing was apparent.At 552,000 crushing all around central portion, greatest on south-east side. At 577,000 lbs. slight spalling rather general in central and lower portion on all sides. At 596,000 lbs. first crushing at top. At 614,000 lbs. slight spalling at top. The second application of a load of 655,000 lbs. caused a very slight increase in the deformations of the column.This column exceeded the capacity of the machine.

8989-3

At 417,000 lbs. scaling at 207, 247 and 221. Slight crushing over spiral at the top. At 446,000 lbs. general crushing over spiral on upper half. Crushing became general over entire surface at 530,000 lbs., but no spalling occurred at this load. At 650,000 lbs. slight spalling all around. After this set of reading had been taken the load was reapplied and another set recorded. A load of 650,000 lbs. was reapplied five times. the time between applications being that necessary to take a set of readings. The load was then reduced to 500,000 lbs. and then reapplied to 650,000 lbs. This operation was repeated five times when a final set of readings was taken. This column exceeded the capacity of the machine.

8990-1

At 254,000 lbs. scaling occurred at the lower gage lines. The first sign of bending occurred at 283,000 lbs. At 303,000 lbs. crushing of the concrete at the center due to the bending of the column. At 343,000 lbs. crushing over spiral at

the top. Spalling commenced at 385,000 lbs. over the central portion. Maximum load 387,300 lbs. At this load considerable spalling occured at the center on the north side, 2 feet from the bottom on the south side, and 3½ feet from the top on both north and south sides.

8990-2

At 267,100 lbs. scaling at 247 2nd 201. Slight crushing over spiral at the top. At 286,000 lbs. scaling at all gage lines on upper level. Very slight crushing over spiral about 3 ft. from top. At 310,000 lbs. crushing over spiral at center began. At 360,000 lbs. spalling 2 ft. above center. Spalling on north-east side at center and south-west at top and bottom at 391,000 lbs. Maximum load was 404,700 lbs. Failure came by bending to the south.

8990-3

At 260,000 lbs. crushing over spiral at the top. At 288,000 lbs. scaling at 243, 245 and 247. At 310,000 lbs. scaling occurred at gage lines 203 and 205. Crushing over spiral at the bottom began at 372,000 lbs. At 375,000 lbs. crushing over spiral on east side slightly above center. At 416,500 lbs spalling at top and bottom on west and at center on east. The maximum load was 418,400 lbs.

8992-1

At 258,000 lbs. very slight crushing over spiral a few inches from the top. At 432,000 lbs. general scaling at all points. At 491,000 lbs. vertical crack on south side extended 2 ft. up from bottom. At 530,000 lbs. general crushing over the entire length, but no spalling. At 549,000 lbs. spalling over the middle third on east and south-east,2 ft. from bottom on

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[illegible]

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[illegible]

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[illegible]

north-west, also near top on north-west. The maximum load was 550,700 lbs.

8992-2

At 229,400 fine vertical hair cracks were noted at the top over longitudinal rods. At 345,000 lbs. scaling at gage line 201. Scaling occurred at gage lines 247 and 241 at 370,000 lbs. At 403,000 lbs. crushing over spiral at the top. At 469,000 lbs. crushing over spiral at the center. Slight spalling on west side at top. At 506,000 lbs. slight spalling on north and west sides at center and on south side at bottom. At 530,400 lbs. (Maximum Load) spiral broke at gage line 45, but there was no indication of this in the action of the machine. A large amount of spalling at the center on north side, at the top and bottom on the south side was noted at this load. Failure came by bending to the south.

8992-3

At 411,000 lbs. scaling occurred at gage line 245. At 424,000 lbs. scaling was noted at gage lines 247, 227, 205 and 207. Slight crushing over spiral at the top. At 432,000 lbs. crushing over spiral on east side at center. At 440,000 lbs. scaling at all points on the upper level. At 446,000 lbs. slight spalling 1 ft. above center on north and east sides. At 456,000 lbs. crushing slightly below center on north side. At 483,000 lbs. spalling at center on north side and at top and bottom on south side. Maximum load was 491,200 lbs. Failure came by bending to the south.

8993-1

At 451,000 lbs. beam of machine indicated some general action, as the passing of the yield point, but no scaling was

noticed. First indication of bending at 468,000 lbs. At 485,000 lbs. small vertical cracks over the longitudinal rods at the top were noted. Column was taking load very slowly at 490,000 lbs. At 507,000 lbs. general crushing at the top and bottom. At 510,000 lbs. spalling at center on south and east sides. At 577,000 lbs. (Maximum Load) practically all of the concrete had spalled off at the center on the east side and at the top and bottom on the west side, marking the points of inflection very distinctly.

8993-2

At 355,000 lbs. slight crushing over spiral at top. First scaling occurred at the bottom at 400,000 lbs. At 407,000 lbs. scaling at all gage points on the upper level. Scaling of steel at the center began at 470,000 lbs. and was complete at 473,500 lbs. At 595,300 lbs. (Maximum Load) spalling at top and bottom on the north-west side and at the center on the south-east side. The points of countra-flexure were found to be 16 in. from the bottom and $15\frac{1}{2}$ in. from the top. There was no irregularity in the spacing of the spiral on the compression side as the spacing bar was located on this side.

8993-3

Crushing over the spiral at top at 360,000 lbs., also scaling at gage line 207. Scaling at gage line 201 at 389,000 lbs. A change in the rate of loading occurred between 470,000 lbs. and 475,000 lbs. Scaling was noted at nearly all points. At 532,000 lbs. crushing near top and bottom on east side. Column bending to the north-east. At 543,000 lbs. crushing began at the center on the west side. At 580,000 lbs. considerable spalling over the

central portion on the west side and at the top and bottom on the east side. At 603,400 lbs. (Maximum Load) spalling increased at the center on the west side.

8994-1

At 254,000 lbs. there appeared to be some yielding by the action of the machine. Slight scaling at gage line 221. A very decided yielding action took place at 275,000 lbs. First bending took place at 305,000 lbs. At 346,000 lbs. spalling over the central portion. The maximum load was 357,700 lbs.

8994-2

At 230,000 lbs. scaling at gage lines 201 and 215. A few short vertical cracks over the longitudinal rods near the top were noted. Crushing 1 ft. above center on the east side at 259,000 lbs. At 276,000 lbs. crushing at center on south-east side and about 18 in. from top and bottom on north-west side. Scaling at the top. At 281,000 lbs. spalling at center and bottom. Failure by bending to the north-west at 297,500 lbs. The spiral was found to be rather unevenly spaced at the center on the compression side, the distances between spirals varying from 1.75 in. to 1.25 in.

8994-3

At 228,000 lbs. scaling at gage line 245. At 256,000 lbs. scaling at gage lines 213, 215, 237 and 247, also crushing at top over spiral.At 285,000 lbs. crushing at lower quarter point on north and west sides. At 301,500 lbs. crushing on the south and east sides at the upper quarter point. At 323,500 lbs. spalling at the quarter points on north and west sides, also at center on north side. At 329,000 lbs. spalling at top and bottom on south-west side. The maximum load was 332,700 lbs.

8995-1

The concrete had been broken off at the top exposing the rod on the north-east side. The load was transmitted to this rod through a thin layer of gypsum plaster. The other rods were covered by a thin layer of cement mortar. At failure all rods seemed to have had equal bearing.

Scaling at 402,000 lbs., also small vertical cracks over the longitudinal rods at the top. At 442,000 lbs. (Maximum Load) spalling at the top and bottom.

8995-2

At 348,000 lbs. scaling at gage lines 221, 233 and 245. At 377,000 lbs. slight crushing over spiral at top. A small amount of bending to the south apparent from deformations at the center. At 410,500 lbs. spalling on north side at center, also on south side at top and bottom. Failed at this load by bending to the south-west.

8995-3

At 365,000 lbs. scaling at gage lines 201 and 207. As soon as load was reapplied scaling occurred at all points at top and upper quarter point.A decided change in the rate of taking load occurred at 385,000 lbs. At 400,000 lbs. crushing at center on west side, also at top on east side. At 403,300 lbs. crushing at bottom on east side. At 403,400 lbs. (Maximum Load) spalling at the center on the west side.

8996-1

First scaling at 412,300 lbs. General over the entire length; also crushing over spiral at the top. Bending began at 469,000 lbs. No increase in crushing at this point. At 500,000 lbs.

spalling 2 ft. from top. At 500,200 lbs. (Maximum Load) spalling at top had increased slightly. Vertical cracks over the longitudinal rods at the top and bottom were noted at this load.

8996-2

At 354,000 lbs. scaling at gage line 211. At 418,000 lbs. scaling at gage lines 213 and 215. At 440,000 lbs. scaling began at gage points on lower level; crushing over spiral at the top on north-east side; no vertical cracks appeared. At 463,000 lbs. crushing at top had increased materially. Crushing began at bottom at 464,500 lbs. At 482,000 lbs. crushing at center on south side. At 496,000 lbs. spalling at center and slightly above on south and south-east sides. At 500,000 lbs. spalling at bottom. The maximum load was 502,400 lbs.

8996-3

At 392,000 lbs. scaling at gage lines 201, 203, 215, 217 and 247. At 421,000 lbs. scaling at gage lines 205 and 207. At 428,000 lbs. crushing over spiral at top on north-west side. At 436,000 lbs. crushing over central portion on east side, also at top on west side. At 449,000 lbs., spalling at top and bottom on north-west and at center on the west side. At 452,000 lbs., bending toward the north rapidly; spalling at center on south side. Failed by bending to the north-west at 452,800 lbs.

8997-1

At 220,000 lbs., scaling at the top at all gage points. A decided yielding occurred at 270,000 lbs. as indicated by the rate of taking load. At 278,000 lbs., crushing over spiral at the top. At 291,000 lbs., slight spalling at upper point of inflection. No crushing at corresponding point at bottom. The only sign of failure at the bottom was a few vertical hair cracks.

8997-2

At 184,000 lbs., scaling at gage line 207. At 198,000 lbs., crushing at top over spiral, also vertical hair cracks over longitudinal rods at the top. At 226,000 lbs., scaling general. At 270,000 lbs., crushing on north and west sides at center. At 277,500 lbs., crushing on south-east side near top and bottom. At 278,100 lbs., (Maximum Load) spalling on north side at center; failed by bending to the south-east.

8997-3

At 224,000 lbs., scaling at gage line 243; crushing over spiral at top on north and north-west sides. At 265,000 lbs. crushing at center on west side and at bottom on east side. At 266,000 lbs., scaling at gage lines 203, 205 and 207. The maximum load was 267,000 lbs.

8998-1

At 400,000 lbs., small vertical cracks over the longitudinal rods at the top; scaling at gage lines 223 and 225. Bending became noticeable at 420,000 lbs. At 425,000 lbs., rate of taking load decreased appreciably. Spalling at the top began at 434,000 lbs. At 434,200 lbs., (Maximum Load) crushing at center on the south side.

8998-2

At 325,000 lbs., crushing over spiral at the top on the east side. At 367,000 lbs., scaling at gage line 203. Apparent scaling at gage line 231. At 382,600 lbs., crushing at center on south side; scaling at gage lines 225, 227 and 237. Rate of taking load decreased materially at 382,500 lbs. Load reached 383,500 lbs. and then fell off rapidly to 382,600 lbs.

with machine sitll running. Machine was stopped for about one minute. After starting again load reached 382,500 lbs. Apparently bending began to be important at load of about 382,500 lbs. when load began to go on slowly.

8998-3

At 226,000 lbs., crushing over spiral at the top. At 367,000 lbs., scaling at gage lines 201 and 211. At 392,600 lbs., (Maximum Load) General slight crushing over spiral at top on the north-west side and at the center on the south-east side. Column bending to the north-west. The bottom of the column was 1 in. too far west and 1.06 in. too far south.

8999-1

At 279,000 lbs., slight scaling at gage line 205. At 384,000lbs., small vertical cracks over longitudinal rods at top. At 418,000 lbs., general scaling of steel. At 438,000 lbs., bending began; crushing 2 ft. above center on north and north-east sides. At 440,200 lbs., (Maximum Load) crushing at top on south side. There was a thin film of concrete the lower ends of the longitudinal rods, but there was no appearance of any crushing having taken place. The longitudinal rods were about 1 in. out of plumb.

8999-2

At 417,000 lbs., crushing over spiral at the top. At 433,000 lbs.,crushing over spiral at the center on the south and east sides. Bending began to increase considerably at a load of 433,400 lbs. At 436,600 lbs., spalling slightly on the south and west sides. The maximum load was 437,100 lbs.

8999-3

A noticeable change in the rate of taking load occurred at 353,000 lbs. Scaling at all points on upper level at this load. No scaling appeared at the upper quarter point at this load. At this same point crushing began about 2 ft. from the top on the west side. At 381,000 lbs., general scaling at all points; crushing 2 ft. above center on the west side. At 383,500 lbs., spalling began at the top and bottom on the east side. The maximum load was 384,500 lbs. At failure there was a point of inflection at the bottom but scarcely any at the top. The column failed by bending to the east and north. At failure the wedges at the top were examined and found to be tight.

6. Analysis of Data: As the load falls off considerably during the time required to take a set of readings, there may be some question as to what should be considered as the load to which the column had been subjected. This falling off of the load increases materially after the concrete core has failed and continues to increase as the maximum load is approached. Had the load been of a static nature and able to follow up any shortening of the column, the probability is that the ultimate would have been reached at a lower load. This phenomenon is due to the plastic or inelastic properties of the materials.

Considerable thought was given as to what cross-section should be used in calculating the unit loads. As the forms were clamped as close to the spiral as possible, the amount of concrete outside of the spiral was very small. In fact, the spiral was visible in most cases except around a spacing bar and where the wooden strips had been placed between the sections of the forms. Even here the concrete was usually less than one-quarter of an inch thick. Before crushing occurs the concrete outside of the spiral gives some assistance and should be considered in determining the unit load on the column. After spalling, however, the concrete within the spiral is all that can be considered as effective since that outside of the spiral has cracked and spalled off. This does not take place over the entire length at the same time, therefore, if the concrete outside of the spiral was to be considered as effective as long as it was intact, the unit loads would vary over the length of the column with respect to the amount of spalling at each particular place. This would make the actual unit load on the column very difficult to determine as the

effective cross-section would not be constant over the entire length of the column. The question arises as to what should be considered as being the effective area at intermediate loads or at the point where the load-deformation curve takes a decided bend.

In order to avoid all of these difficulties and insure the same degree of accuracy in the determination of the unit loads, it was finally decided to use the diameter as measured from out-to-out of spiral as giving the most representative area under the conditions. In each case the average of six measurements taken at the top, center and bottom, two at each height at right angles to each other, was used to determine the effective area of the column. This value was used to determine the unit loads throughout the tests.

In studying these tests and in comparing them with other tests it should be remembered that the columns were straight and that the concrete was as uniform a mixture as it is possible to obtain. The spiral reinforcement was in good condition, there being only a few slight variations in the pitch. In some instances the spacing bars were not straight due to a slight uncoiling of the spiral, but this was not sufficient to affect the results of the tests in any case. The longitudinal reinforcement was as straight as it is possible to obtain. The results are therefore thought to be relatively reliable, even though the control cylinders seemed rather erratic and gave comparatively low results. This would reduce the load resisted by the concrete and cause it to act as a non-cohesive material at loads below the standard for a 1-2-4 mix.

The Effect of Length upon the Strength of the Column: From the curves on page 245 showing the effect of length upon the strength of the columns it is seen that a term which would represent this effect would change with each combination of reinforcement. The curve for 1 per cent of spiral and 2 per cent of longitudinal reinforcement might easily be replaced by a straight line which would give a reduction in ultimate load of approximately 12 per cent of the strength of a 5 ft. column for each increase in length of 5 ft. between length of 5 ft. and 20 ft.

The curves representing the other combinations of reinforcement, namely, 1 per cent of spiral and 5 per cent of longitudinal reinforcement, and 2 per cent of spiral and 5 per cent of longitudinal reinforcement, tend to show that the spiral is more effective at a length of 15 ft. than at a length of 10ft. This cannot be considered as being of any significance as peculiarities have arisen in previous tests of 15 ft. columns. It was thought that there might be some irregularity in the guides for the head of the machine at this point, but the position of the head of the machine at the ultimate loads of 5 ft. and 20 ft. columns was found to be practically the same as at the ultimate loads for the 15 ft. columns. Therefore, this phenomenon remains as one of the unexplained peculiarities of the tests.

The dotted portion of the curves indicate their location according to the assumed maximum loads as determined on page 246. Here the curves are plotted for each set showing the unit loads necessary to produce certain stresses in the spiral for columns 5 ft. long. The two lower curves run up to the maximum load. The two upper curves have been continued by extending the curves as

nearly like those that reached a maximum load as possible. A check on the assumed maximum loads may be obtained from tests made by Mr.J.O.Draffin, Research Fellow in the Engineering Experiment Station, University of Illinois, on columns of the same length and the same combinations of reinforcement with eccentricities of 1 in. and 1 1/2 in. Theoretically, the ultimate loads for eccentricities of 1 in. and 1 1/2 in. should be approximately 60 per cent and 50 per cent of that under concentric loading respectively. The following table shows these relations for the 5 ft. and 10 ft. columns.

Reinf'ment. —6	Length	Ult. Load Conc.	Ult. LOad 1"Ecc.	Theo' tical Ratio	Actual Actual Ratio.	Ult. Load 1.5" Ecc.	Theo' tical Ratio	A Actual Ratio.
1%Spi. 2%Long.	5	3777	2760	.636	.731	2035	.538	.539
do.	10	3513	2257	.648	.640	1988	.537	.565
1%Spi. 5%Long.	5	5750	3418	.653	.595	3240	.556	.564
do.	10	4617	2892	.652	.625	2717	.555	.590
2%Spi. 5%Long.	5	6500	3697	.651	.569	3133	.554	.482
do.	10	4980	2990	.652	.600	2775	.554	.557
Average				.649	.627		.549	.549

The values given in the above table tend to show that the assumed average maximum load for the set having 1 per cent of spiral and 5 per cent of longitudinal reinforcement was slightly too low, while that for the set having 2 per cent spiral and 5 per cent longitudinal reinforcement was about 3 per cent too high. If, for either one of these cases, the ultimate load as reached with either eccentricity is divided by the corresponding

theoretical ratio, it is found that the quotient multiplied by the area of the column is less than 600,000 lbs., the capacity of the machine. This discrepancy may be due to the fact that the value of n as used in calculating the theoretical ratio, namely 15, was not constant for all of the columns. Reference to table VIII page 294 will show this to be true.

While the increase in ultimate load due to an increase in the percentage of spiral reinforcement at a length of 20 ft. is very small, it is thought that the 20 ft. columns having 1 per cent of spiral and 5 per cent of longitudinal reinforcement were unusally strong as they carried an average unit load at ultimate which was only 70 lbs. less than that of the 15 ft. columns of the same reinforcement. It is thought that the curve should be similar to that representing the columns having 2 per cent of spiral and 5 per cent of longitudinal reinforcement except that the slope should become less as the 20 ft. length is approached.

On pages 246 to 247 are shown curves giving the load necessary to produce certain unit stresses in the spiral for columns of the same length but different combinations of reinforcement. The curves for the 5 ft. columns have been extended to a stress of 5,000 lbs. per sq. in. in the spiral in order to determine their general shape at low stresses in the spiral. From the general average curves on pages 208 to 244 it can be seen that the spiral does not take any appreciable stress until the longitudinal steel has reached its yield point. In fact, a stress of 5,000 lbs. per sq. in. in the spiral reinforcement is seldom obtained before this point is reached. Between stresses

of 10,000 lbs. per sq. in. and 40,000 lbs. per sq. in. in the spiral, the curves are practically straight lines. Between these limits the stress is proportional to the deformation in the spiral. Beyond the yield point of the spiral we find an abrupt rise in the curve. This is due to the rapid increase in deformation with slight increase in stress at this point.

The curves for the 15-ft. and 20-ft. columns do not show this rapid rise beyond the yield point of the spiral as the columns failed by bending before this stress was reached.

On page 248 and 249 are curves showing the unit loads necessary to produce certain stresses in the spiral for the various lengths of columns tested. A rise in the curve for the 10 ft. length is prevalent for all combinations of reinforcement as well as for unit stresses in the spiral varying from 10,000 lbs. to 30,000 lbs. This can only be attributed to the concrete. If reference is made to table VIII page 294, it is seen that the cylinder strengths for the 5 ft. columns were approximately as much lower than those for the 10 ft. columns as the load necessary to produce stresses of 10,000 lbs., 20,000 lbs, and 30,000 lbs. per sq. in. in the spiral reinforcement of the 5-ft. columns was lower than that for the 10-ft. columns for all combinations of reinforcement. This condition will also prevail for some of the 15-ft. columns.

As the concrete fails by crushing at practically the same load that causes scaling of the longitudinal steel, a portion of the additional strength is attributed to the spiral. In order that the stress may reach the spiral it must be transmitted by the concrete. If the concrete was intact and could be consider-

ed as a cohesive material this would not occur as the spiral shows very little indication of stress before the longitudinal steel has reached its yield point and the concrete has begun to crush. At this stage the concrete must be considered as a semi- or partially cohesive material. The degree of cohesiveness would become less as the load increased and a point might be reached where it would act like a non-cohesive material such as sand. This stage, however, was not reached in this series of tests. The fact that the difference between the loads necessary to produce stresses of 10,000 lbs.,20,000 lbs.,and 30,000 lbs. per sq. in. in the spiral for the 5-ft. and 10-ft. columns for all combinations of reinforcement is practically constant seems rather phenomenal due to the decreasing degree of cohesiveness as the load increases. It is evident that the degree of cohesiveness is not reduced to any extent between stresses of 10,000 and 30,000 lbs. per sq. in. in the spiral.

If the action is similar to that obtained under continued loading or long time tests, such as the gradual increase in the deformations with time under no change in the load, the phenomenon would be due to a flow of the concrete within the spiral with only a slight or no change at all in the degree of cohesiveness. The concrete outside of the spiral undergoes a reduction in its degree of cohesiveness as it spalls off, but this is ~~undou~~ doubtedly due to the bulging of the column in a lateral direction. That within, being restrained by the spiral, is under different conditions and cannot be compared with that outside of the spiral.

Load Necessary to Produce Bending: On page 250 are curves showing the load necessary to produce a deflection of 0.1 in. for all

of the columns tested in which a deflection of this amount was obtained. The 5-ft. columns with 2 per cent of spiral and 5 per cent of longitudinal reinforcement deflected less than 0.1 in.

The loads for the 20-ft. columns with 5 per cent of longitudinal reinforcement seem high as compared with the other lengths having the same amount of longitudinal reinforcement. An increase of 3.3 per cent in the longitudinal reinforcement has a decided effect upon the load necessary to produce a deflection of 0.1 in. The following table gives in lbs. per sq. in. for 1 per cent of longitudinal reinforcement, the increase in the load required to produce a deflection of 0.1 in.

Length. ft.	Increase in load per 1 per cent of long. steel to produce 0.1-in. deflec.
5	505
10	266
15	251
20	360

This table is based on a comparison of the loads for the columns having 1 per cent of spiral and 2 per cent and 5 per cent of longitudinal reinforcement. The change in direction in the curve for the columns having 1 per cent of spiral and 5 per cent of longitudinal reinforcement at the 15-ft. length is due to the increase as shown in the above table.

By comparing the sets having 5 per cent of longitudinal reinforcement the increase per 1 per cent of spiral is seen to be practically constant for lengths of 10 ft., 15 ft. and 20 ft. The average increase in the unit load per 1 per cent of spiral is 220 lbs. This is as would be expected as the spiral cannot

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[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

[illegible]

[illegible]

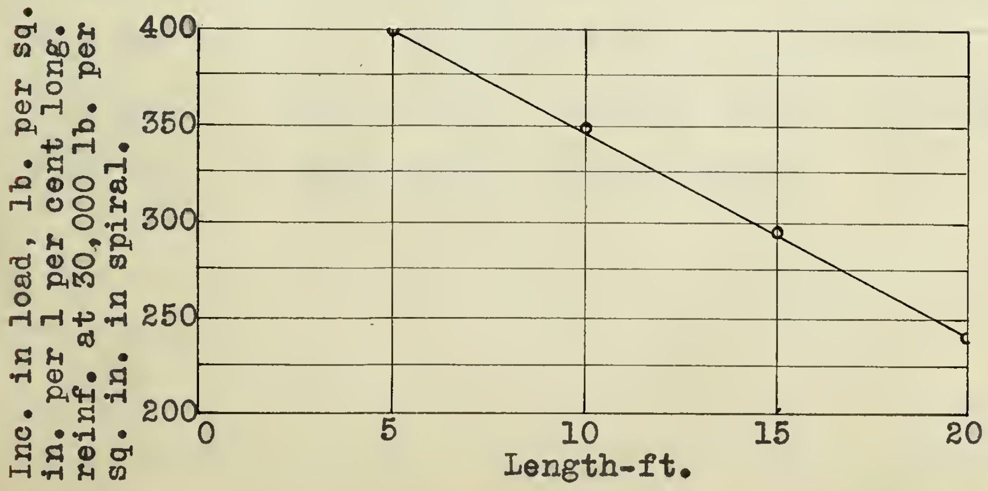
give much resistence to bending at any length.

Effect of Longitudinal Reinforcement: In order to determine the rate of increase in strength per 1 per cent of longitudinal reinforcement it is necessary to compare the sets having 1 per cent of spiral reinforcement. As only two points on the curve have been determined by this series of tests, it has been drawn as a straight line. This rate of increase is affected by the amount of spiral reinforcement present. From other tests it has been found that the larger the percentage of spiral, the less the increase in strength per 1 per cent of longitudinal reinforcement. With a certain per cent of spiral reinforcement and varying amounts of longitudinal reinforcement it has been found that the rate of increase per 1 per cent of longitudinal reinforcement decreases as the percentage of longitudinal reinforcement increases. Curves showing the effect of longitudinal reinforcement on the strength of the columns can be found on page251.

At the ultimate load the increase in strength per 1 per cent of longitudinal reinforcement was found to be practically the same for lengths of 10 ft., 15 ft., and 20 ft. For a 5-ft. length however, the increase in strength per 1 per cent of longitudinal reinforcement is about 90 per cent greater than the average for the 10-ft., 15-ft., and 20-ft. lengths. The following table gives, for the ultimate load, and for the load producing a stress of 30,000 lbs. per sq. in. in the spiral, the increase in strength per 1 per cent of longitudinal reinforfement with columns of varying lengths. All columns noted had 1 per cent of spiral reinforcement. All values given are the difference between the averages of three tests.

Length in ft.	Increase in Load, lbs. per sq. in. per 1 per cent of longitudinal reinforcement.	
	At Ultimate	At 30,000 lbs. per sq. in. in the spiral.
5	590	400
10	340	348
15	230	292
20	330	241

The small increase in strength per sq. in. at ultimate load for the 15-ft. columns may be due to variations in the strength of concrete as the control cylinders show poorer concrete for the 15-ft. columns with 1 per cent spiral and 5 per cent longitudinal reinforcement than for the 20-ft. columns with the same reinforcement. The question as to the effectiveness of the concrete at the ultimate load of columns of this length still remains. At a stress of 30,000 lbs. per sq. in. in the spiral the additional load per 1 per cent of longitudinal reinforcement, when plotted as ordinates against column length as abscissas gives a straight line as shown below.



For each increase in length there in a reduction in the amount of increase per 1 per cent of longitudinal reinforcement at a stress of 30,000 lbs. per sq. in. in the spiral of 13 per cent of the rate for a 5-ft. column. This condition holds for the columns having only 1 per cent of spiral reinforcement.

The Effect of Spiral Reinforcement: In this case the sets having 5 per cent of longitudinal reinforcement and varying amounts of spiral reinforcement are compared. The curves are shown on page 251.

From previous tests, it has been found that the increase in strength per 1 per cent of spiral varied with the amount of longitudinal reinforcement present, the increase in strength being reduced as the percentage of longitudinal reinforcement increased. Length would also affect this increase since the effectiveness of the spiral would decrease as the length increased whether the percentage of longitudinal reinforcement increased or not. This fact is brought out by this series of tests.

As only two points on the curve were determined by this series of tests, it has been drawn as a straight line. The increase in strength at ultimate load and at a stress of 30,000 lbs. per sq. in. in the spiral due to 1 per cent of spiral reinforcement is shown in the following table. All columns noted had 5 per cent of longitudinal reinforcement.

Length in ft.	Increase in Load, lbs. per sq. in. per 1 per cent of spiral reinforcement.	
	At Ultimate	At 30,000 lbs. per sq. in. in the spiral.
5	560	313
10	200	260
15	340	312
20	40	---

The above values tend to show that the effectiveness of the spiral was about the same for the 15-ft. length as for the 10-ft. length. In fact, the tests show an increase in the effectiveness of the spiral at a length of 15-ft. over that at a 10-ft. length. This action cannot be accredited and must be considered as one of the discrepencies of the tests. The extremely low value for the 20-ft. length indicates that an increase in the percentage of spiral reinforcement would not be the proper solution if additional strength is desired for a column with a ratio of l/d equal to 20 or more.

At a stress of 30,000 lbs. per sq. in. in the spiral we have an entirely different condition. Here the increase in strength per 1 per cent of spiral reinforcement is practically the same for lengths of 5-ft., 10-ft., and 15-ft. The fact that the 20-ft. columns failed by bending before this stress in the spiral reinforcement was reached indicates that beyond a length of 15-ft. the effect of length has a decided bearing upon the effectiveness of the spiral reinforcement.

Effect of Spiral and Longitudinal Reinforcement on Poisson's Ratio: Poisson's ratio is used in this thesis as being the ratio between the lateral deformation and the longitudinal deformation at a certain unit load or particular stage of the test.

By referring to the curves on page 252, it is readily seen that within the limits of length tested, a change from 2 per cent of longitudinal reinforcement to 5 per cent of longitudinal reinforcement has no material effect on the value of Poisson's ratio at any stage of the test. The curves marked A and B representing the sets having 1 per cent of spiral and 2 per cent of longitudinal reinforcement, and 1 per cent of spiral and 5 per cent of longitudinal reinforcement respectively,could be averaged at each particular stress in the spiral and a curve plotted therefrom which would be representative of the two sets. As the stress in the spiral increases there seems to be a slight increase in Poisson's ratio.This increase is more rapid in the 15-ft. and 20-ft. columns than in the 5-ft. or 10-ft. columns. For the 15-ft. and 20-ft. columns the curves generally show a marked reduction in the rate of increase in Poisson's ratio when bending has become an important factor. This general statement does not apply to the 20-ft. columns having the largest percentage of reinforcement as only one point can be plotted for them, namely, at a stress of 10,000 lbs. per sq. in. in the spiral.

A variation in the amount of spiral reinforcement has a decided effect upon Poisson's ratio for the 5-ft. and 10-ft. columns. A reduction varying from 25 per cent to 40 per cent in the value of Poisson's ratio is realized for stresses in the spiral as high as 40,000 lbs. per sq. in. as compared to the values

obtained when 1 per cent of spiral reinforcement is used. As the length of the column increases this increase in Poisson's ratio due to an increase of 1 per cent in the amount of spiral reinforcement becomes less pronounced. This result indicates the decreasing effectiveness of the spiral reinforcement as the length increases.

Effect of Length upon Poisson's Ratio: The curves on page 253 seem to indicate that length has very little if any effect on Poisson's ratio.At the lower stresses in the spiral there seems to be a slight tendency to decrease as length increases. This condition is reversed at a stress of 30,000 lbs. per sq. in. in the spiral. The condition at 40,000 lbs. per sq. in. in the spiral is questionable as none of the 15-ft. or 20-ft. columns sustained a load great enough to develop this stress. In general it may be said that with a certain unit stress in the spiral reinforcement Poisson's ratio is practically constant for columns varying from 5-ft. to 20-ft. in length.

E_c of the Columns: The modulus of elasticity of the columns was calculated from the following relation:

$$EA = E_c A_c + E_s A_s$$

$$E_c = \frac{EA - E_s A_s}{A_c}$$

E = the modulus of the column as a whole,

A = the cross-section of the column,

E_c = the modulus of the concrete of the column,

A_c = the area of the concrete of the column,

E_s = the modulus of the longitudinal reinforcement,

A_s = the area of the longitudinal reinforcement.

E was determined from the slope of the curve for the longitudinal

deformation in the concrete shown by the general average curves on pages 208 to 244. In this relation it is assumed that the longitudinal deformations for the concrete and steel are equal. If the curves marked steel and concrete are compared, the unit deformations at a load of 600 lbs. per sq. in. are nearly identical for all of the columns. E was found at this point.

By consulting the curves at the bottom of page 254 , it is noticed that there is a decrease in the modulus of elasticity of the concrete of the columns with an increase in length. This seems to be true regardless of the amount of reinforcement present. No conclusion can be drawn as to the effect of the reinforcement with a constant length of column as the curves cross and recross between the lengths tested.

The general downward tendency with an increase in length is attributed to a decrease in the density and compactness of the concrete in the longer columns. This is probably due to the interference of the reinforcement with the thorough puddling of the concrete around the reinforcement while in the state of fabrication. The tendency of the concrete to settle away from the spiral on the underneath side while setting, develops voids which would tend to reduce the density and compactness of the mass. The probability of obtaining a uniform mixture throughout the entire length of the longer columns is less than with a short column. The fact that the concrete was dropped into a form as long as the column which was being made would possibly cause some separation of the materials especially in the 15-ft. and 20-ft. columns. This may be another reason for the decrease in the modulus of elasticity of the concrete of the columns as the

length increased. The modulus of elasticity of the concrete of the columns was less than that of the control cylinders in every case.

Variations in the Value of n: As the value of n depends upon the value of E_c discussed in the preceeding paragraph, it is seen that as the length increases the value of n increases slightly. The curves showing the effect of length upon the value of n can be found on page 254. If these curves are replaced by a straight line we would have the following values for n at the various lengths of columns investigated.

Length-ft.	n
5	13.86
10	14.99
15	16.12
20	17.25

These values are believed to be fairly representative.

7. Conclusions: The following conclusions are based upon a study of the data obtained from this series of tests.

1. The initial modulus of elasticity of the column as a whole is independent of the amount of spiral reinforcement, but above 2 per cent of longitudinal reinforcement there in an increase of about 300,000 lbs. per 1 per cent of longitudinal reinforcement. This holds for longitudinal reinforcements as high as 5.3 per cent.

2. The initial modulus of the concrete of the column is independent of the amount of reinforcement present, but decreases slightly as length increases.

3. The effect of spiral reinforcement upon the strength of 20-ft. columns is very small. At a stress of 30,000 lbs. per sq. in. in the spiral, the effectiveness of the spiral reinforcement is practically constant for lengths of 5-ft., 10-ft., and 15-ft.

4. The spiral reinforcement does not take any appreciable stress until the longitudinal reinforcement has reached its yield point.

5. Between stresses of 10,000 and 40,000 lbs. per sq. in. in the spiral, the stress in the spiral is directly proportional to the applied load. This is true for all of the lengths of columns tested.

6. The effectiveness of spiral reinforcement to resist bending is slight. It is practically constant for lengths of 10-ft,, 15-ft., and 20-ft.

7. The effectiveness of longitudinal reinforcement as to its resistance to bending decreases as the length of the column increases.

8. The increase in load due to one per cent of longitudinal reinforcement decreases as the length increases.

9. The decrease in strength between the 5-ft. and 10-ft. columns increases as the amount of reinforcement increases; between the 10-ft. and 15-ft. columns it is practically constant for all combinations of reinforcement.

10. The increase in load due to one per cent of spiral reinforcement decreases as the length increases.

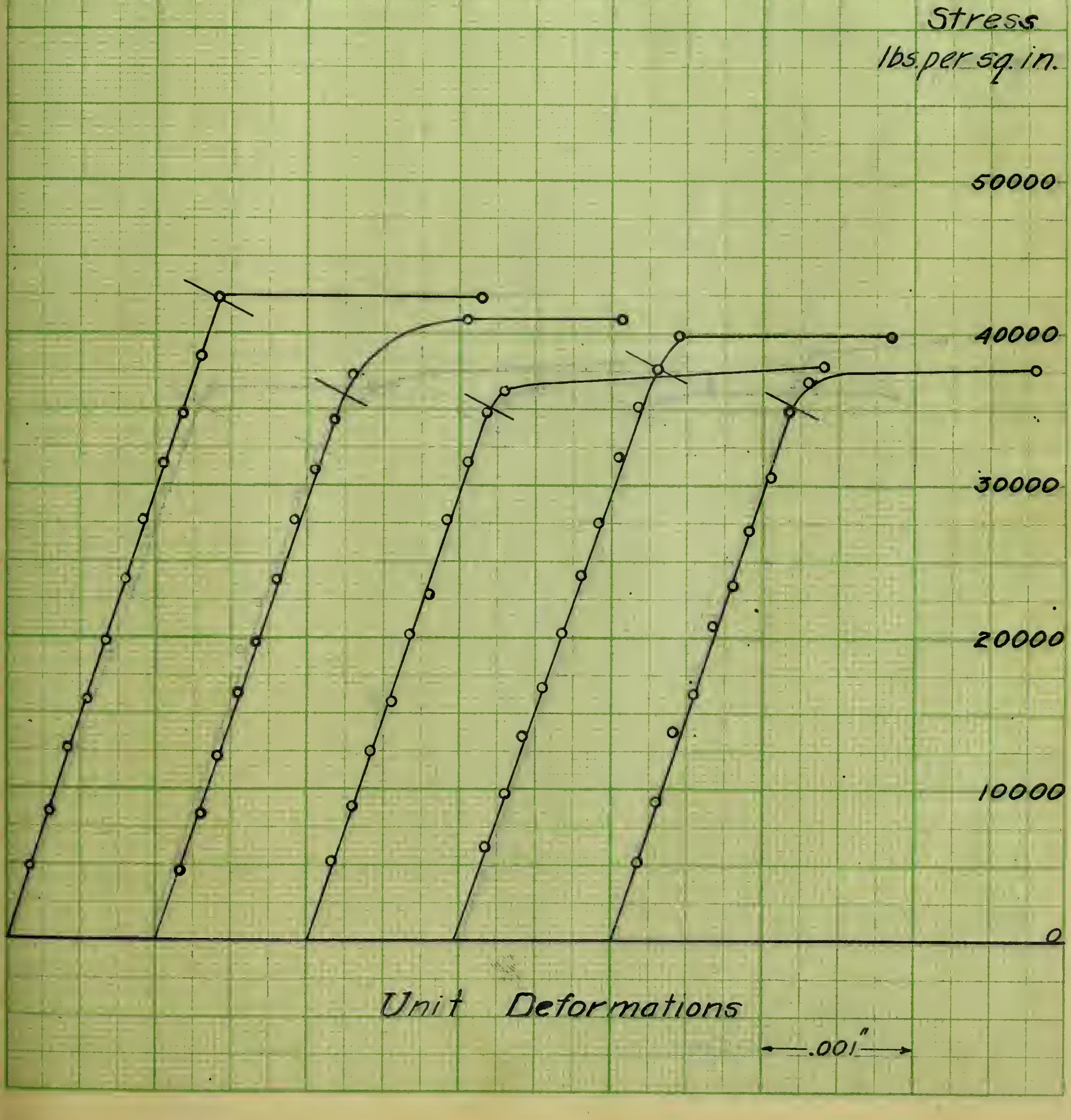
11. Poisson's ratio is practically constant for the two percentages of longitudinal reinforcement used in this series of tests.

12. There is some tendency for Poisson's ratio to increase slightly as the length of the column increases, also as the stress in the spiral reinforcement increases.

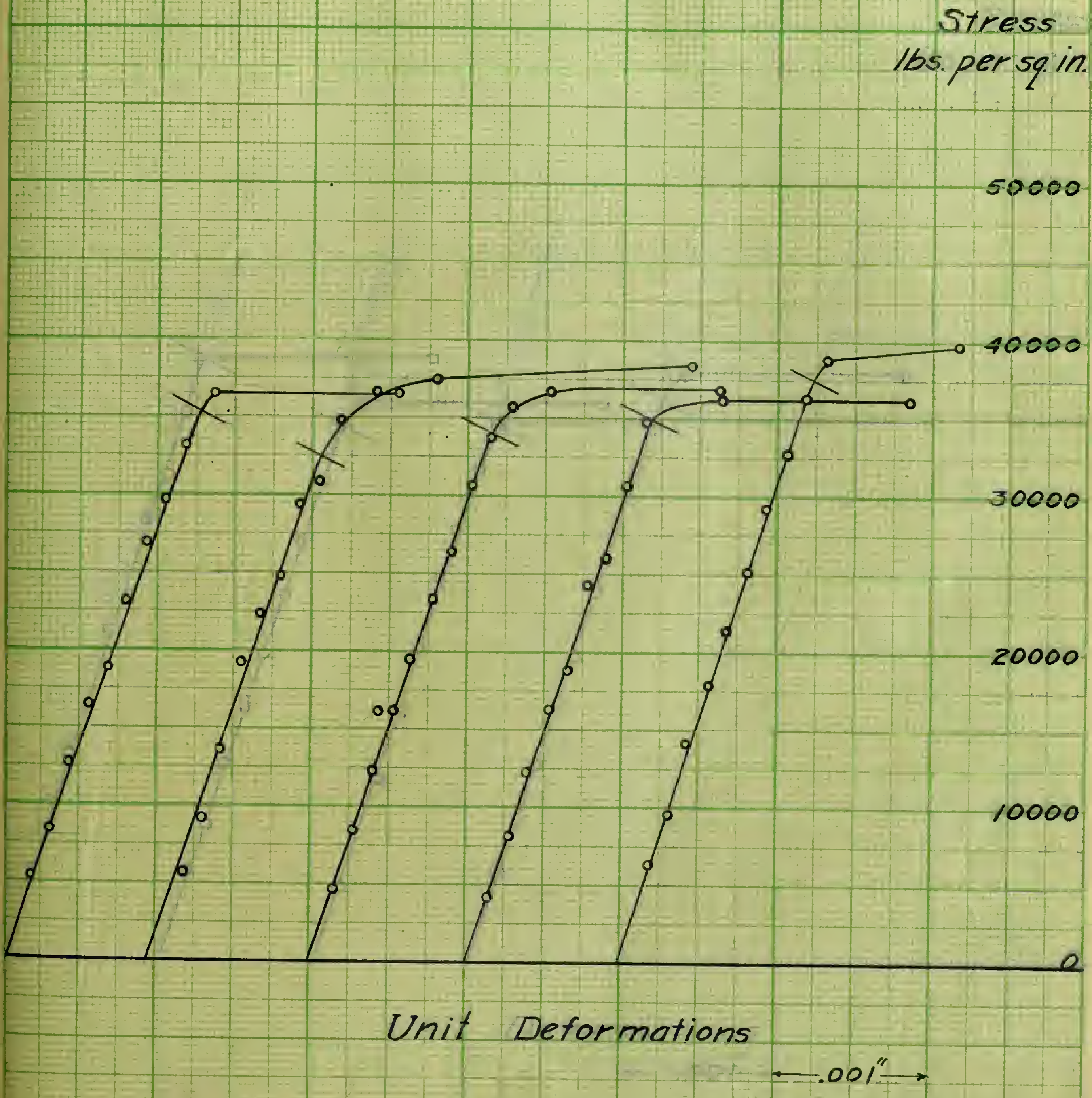
13. An increase in the percentage of spiral reinforcement causes a decided reduction in the value of Poisson's ratio for the 5-ft. and 10-ft. columns. This effect is not so pronounced for the 15-ft. and 20-ft. columns.

14. At stresses of 10,000 and 20,000 lbs.per sq. in. in the spiral, Poisson's ratio is practically constant for all of the lengths of columns tested.

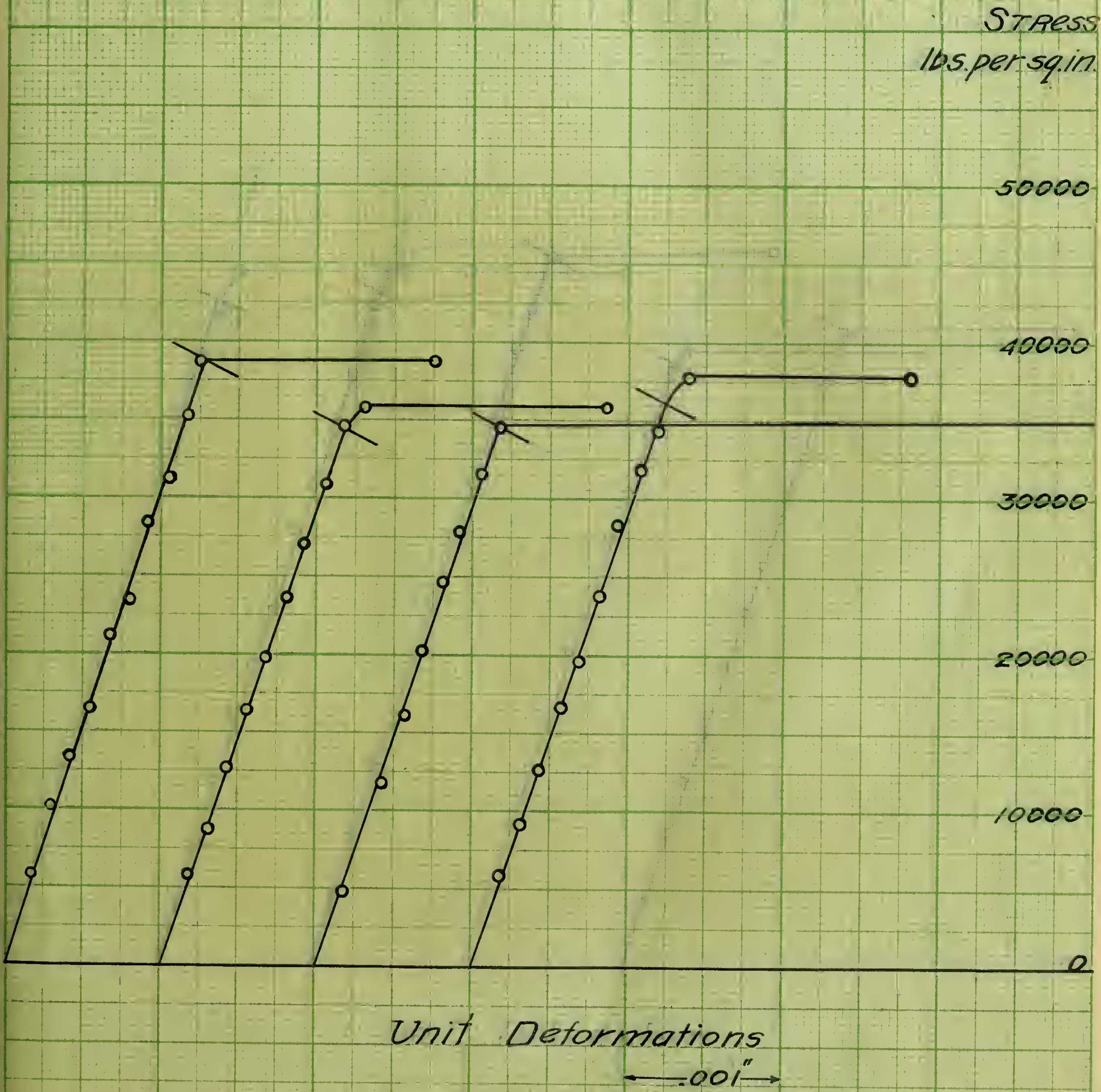
STRESS—DEFORMATION CURVES
FOR
5/8" LONGITUDINAL REINFORCEMENT



STRESS—DEFORMATION CURVES
FOR
5/8" LONGITUDINAL REINFORCEMENT



STRESS-DEFORMATION CURVES FOR 5/8" LONGITUDINAL REINFORCEMENT



STRESS-DEFORMATION CURVES
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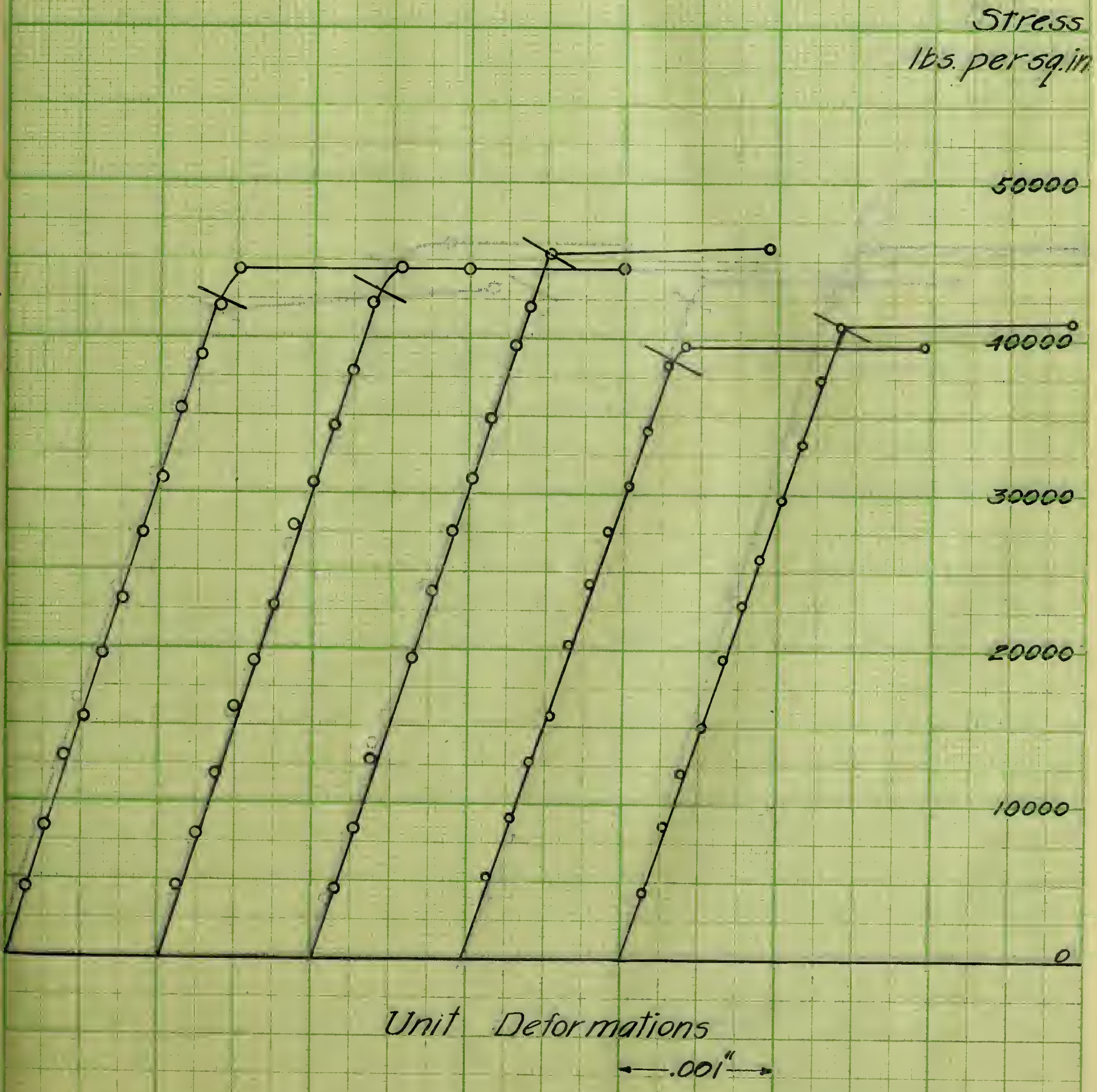
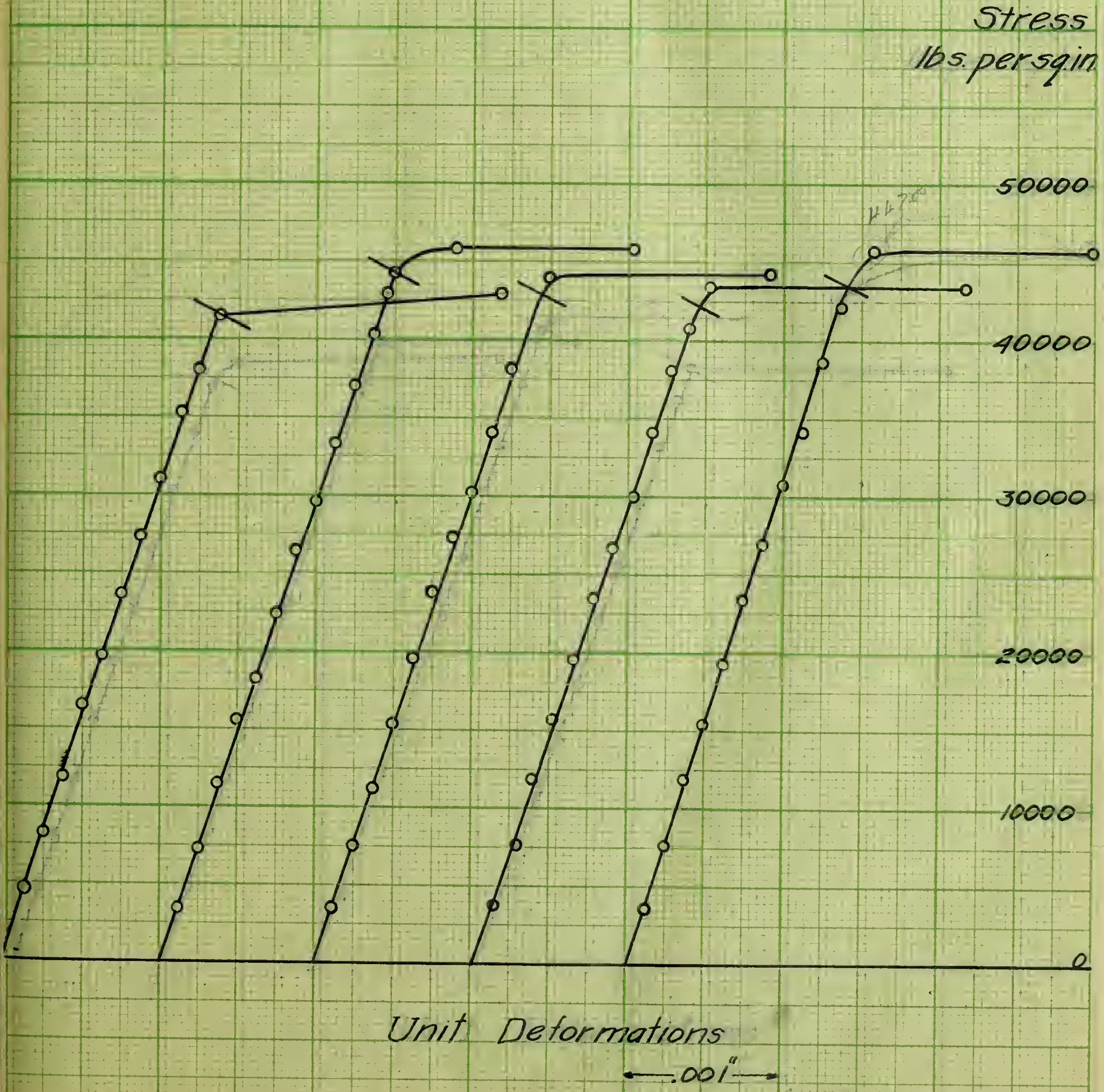
1" LONGITUDINAL REINFORCEMENT



STRESS-DEFORMATION CURVES
FOR
1" LONGITUDINAL REINFORCEMENT



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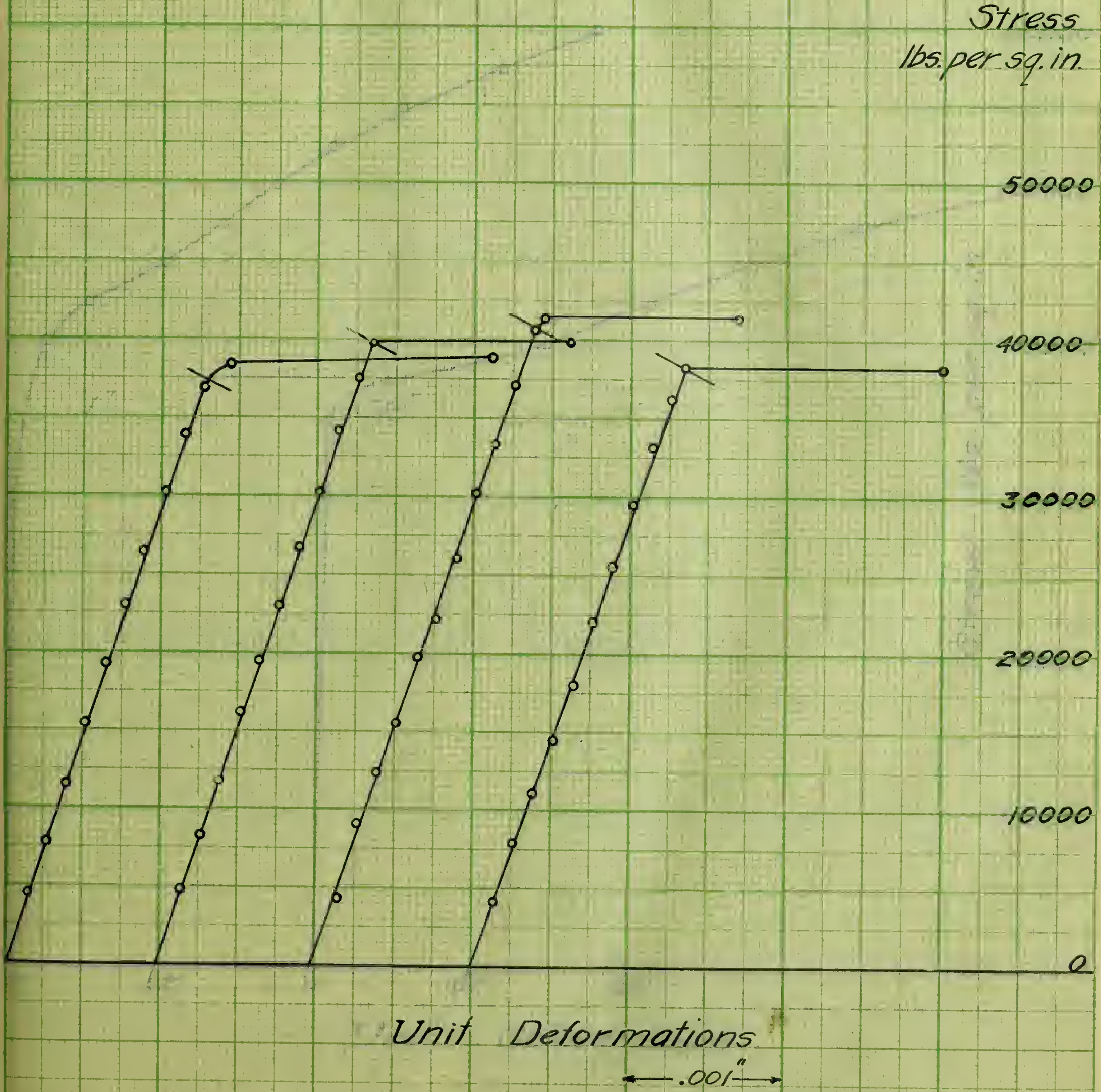
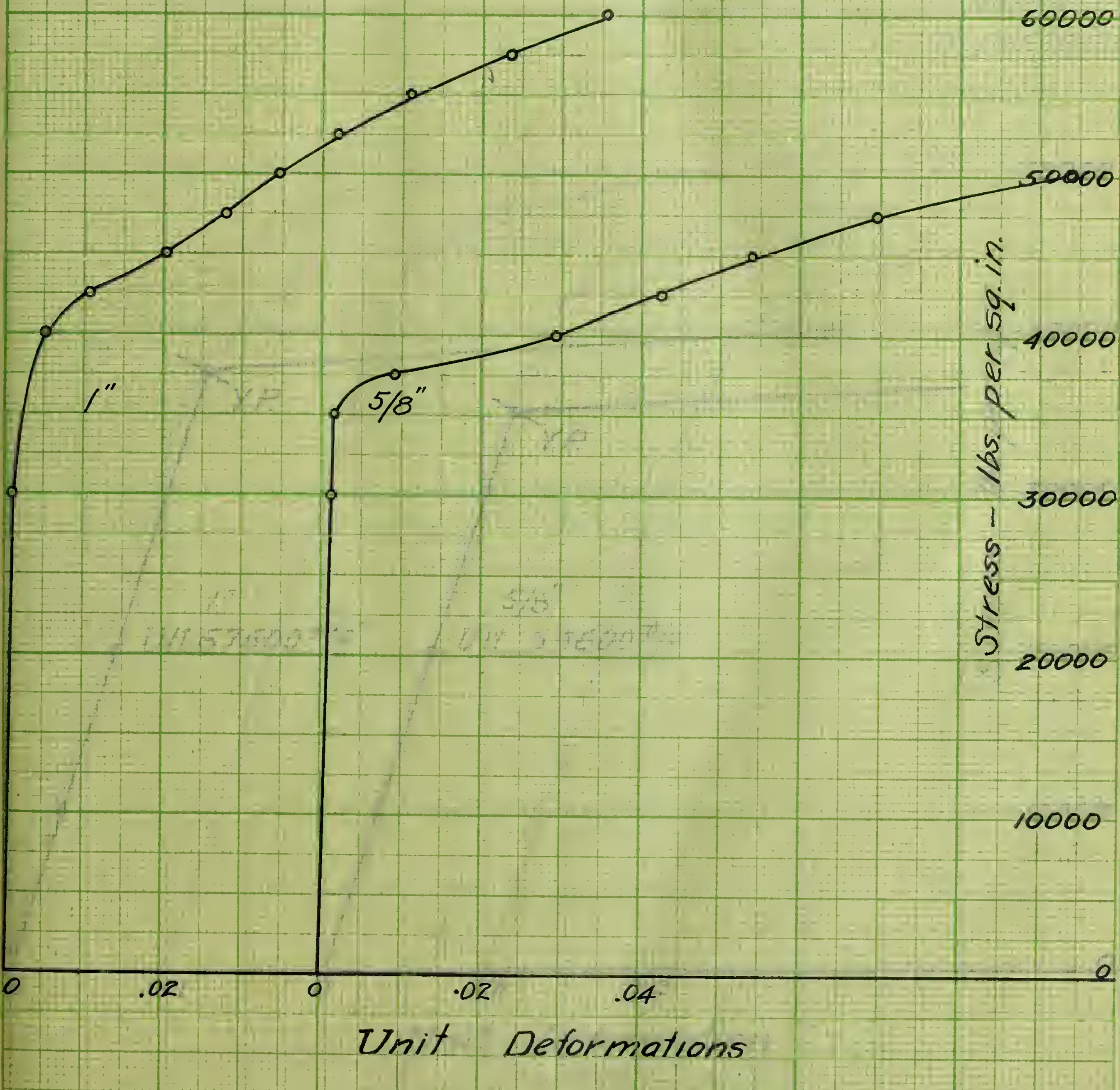
FOR
1" LONGITUDINAL REINFORCEMENT



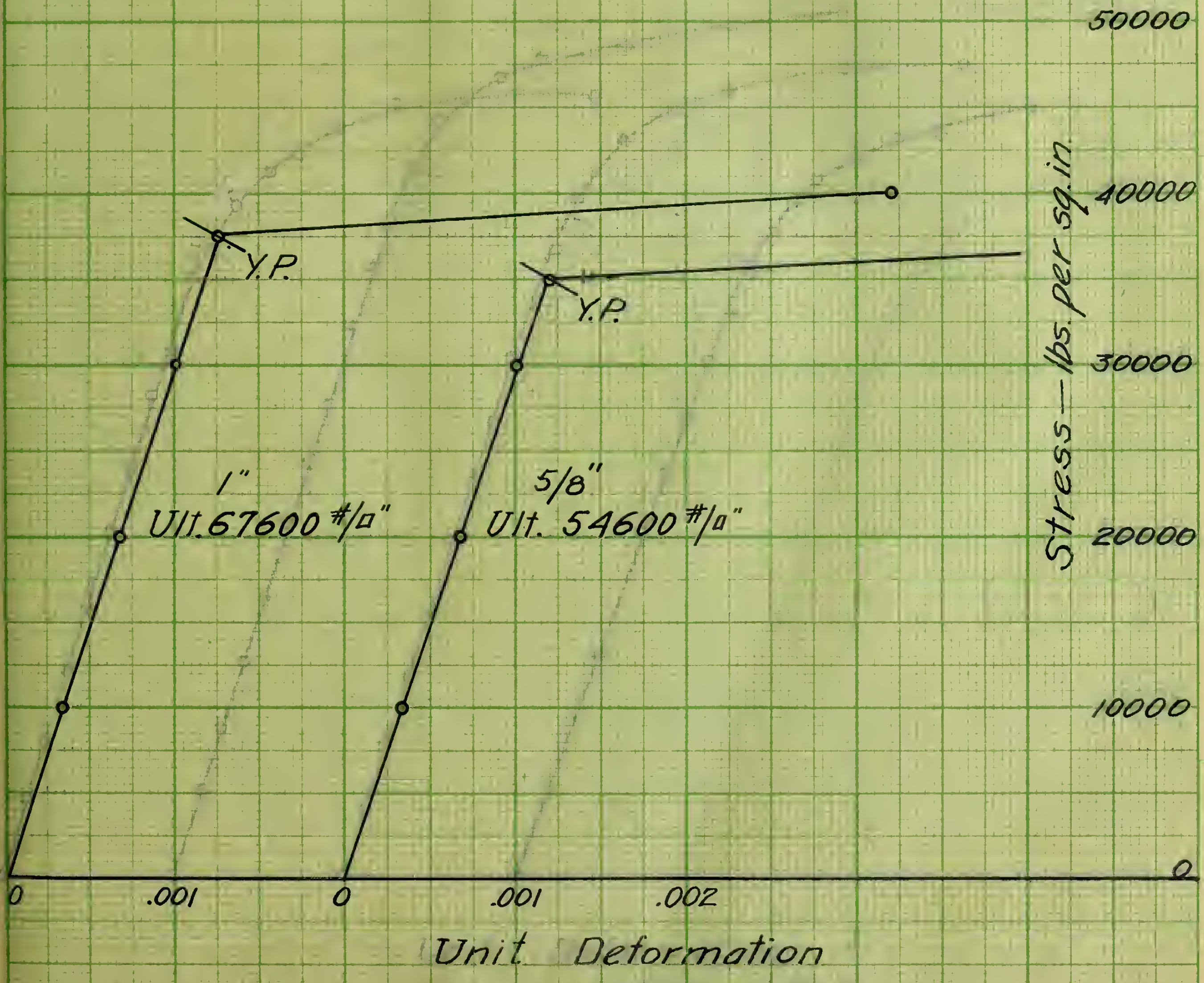
AVERAGE
STRESS-DEFORMATION CURVES
FOR
LONGITUDINAL REINFORCEMENT

EACH CURVE IS AN AVERAGE OF 14 TESTS

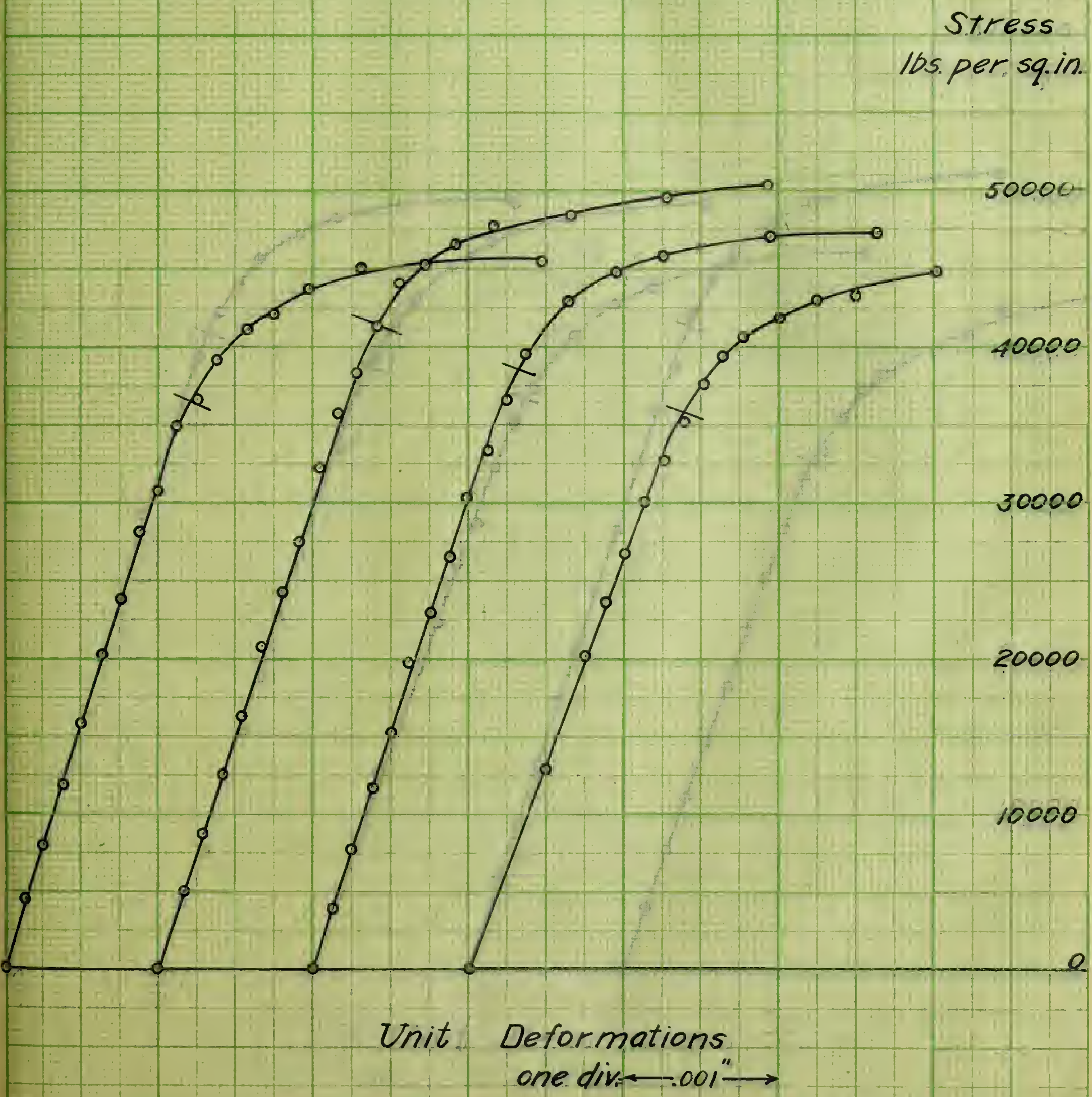


AVERAGE STRESS-DEFORMATION CURVES FOR LONGITUDINAL REINFORCEMENT

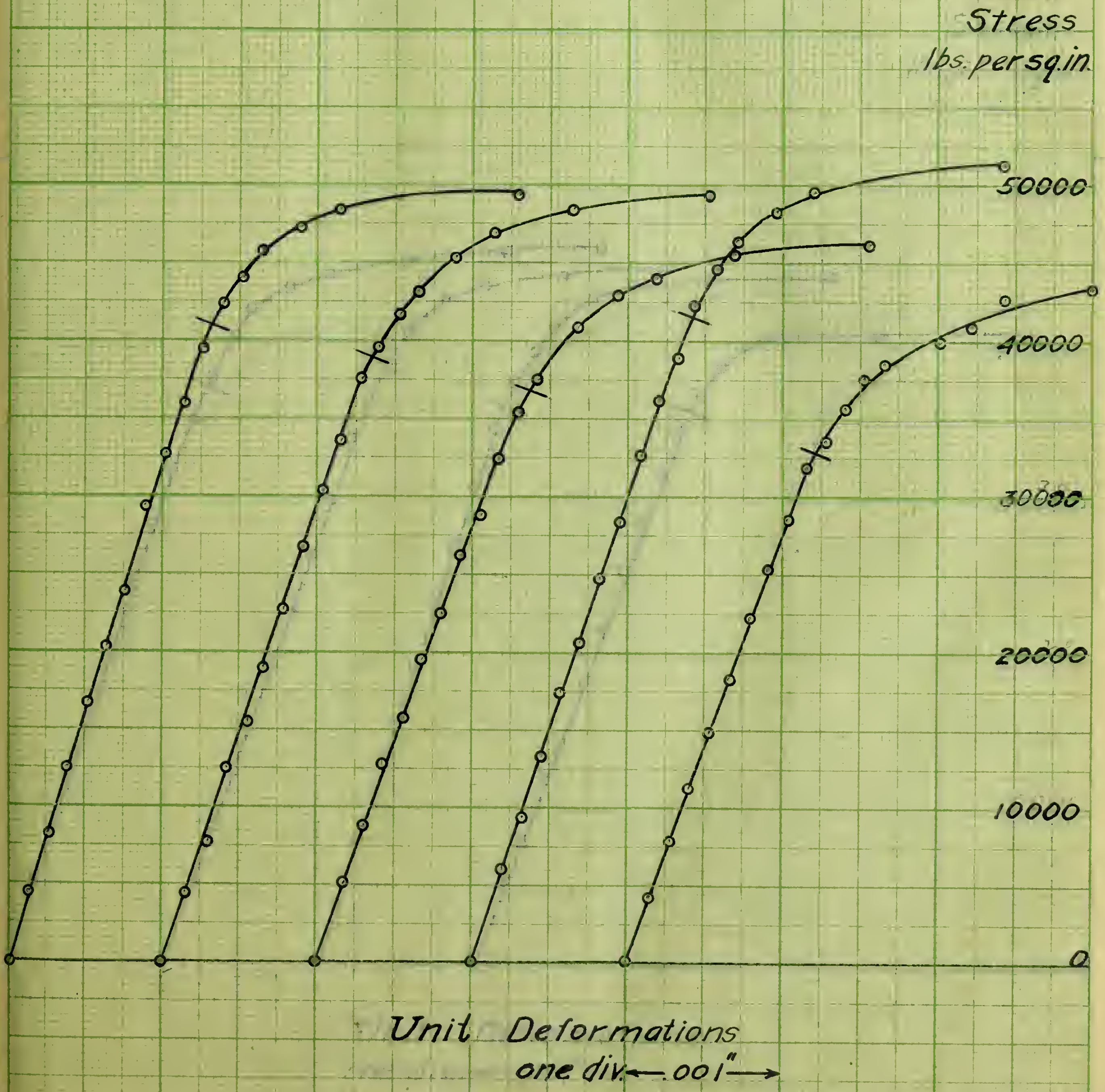
EACH CURVE IS AN AVERAGE OF 14 TESTS



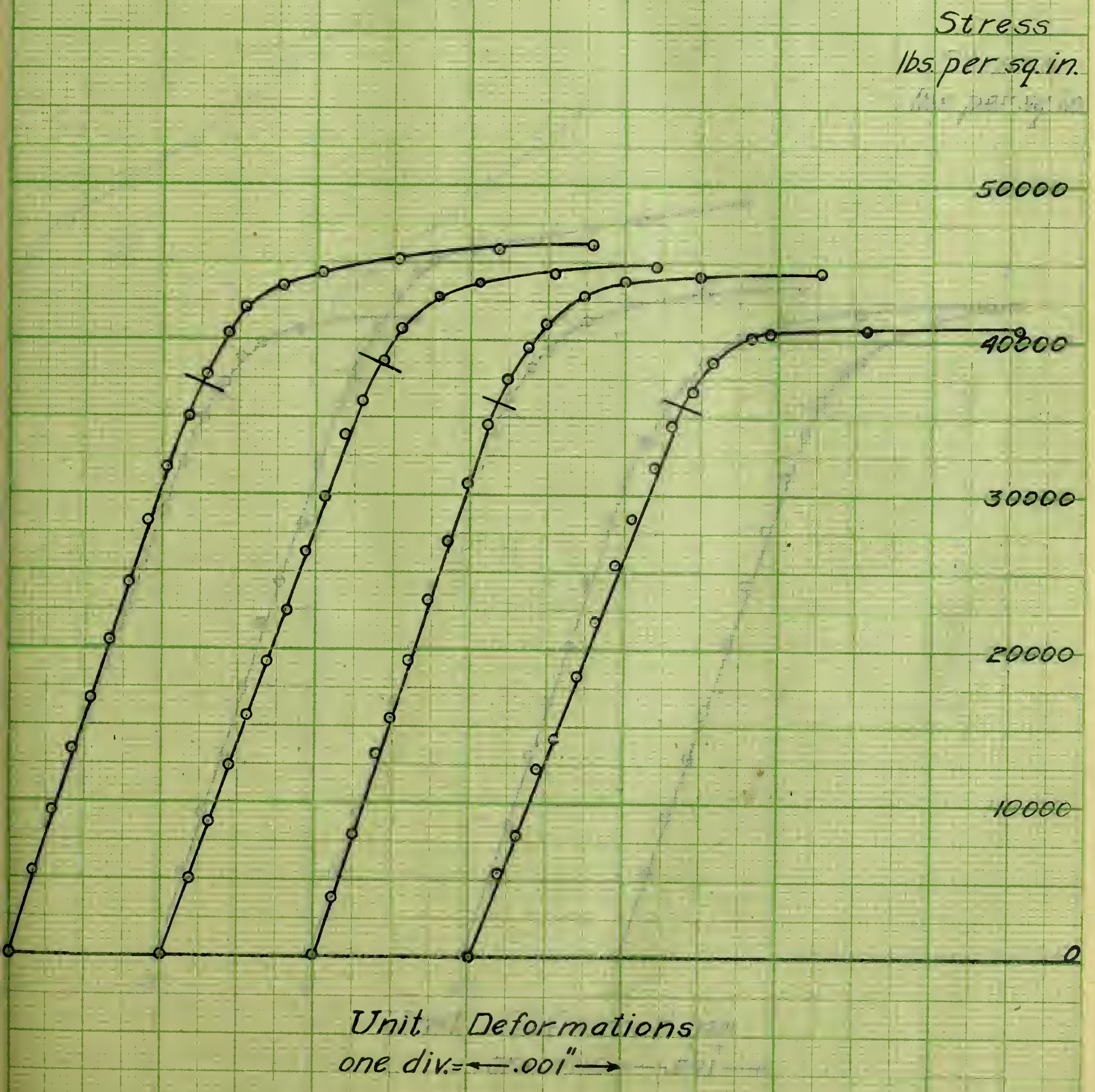
STRESS-DEFORMATION CURVES FOR 1/4" SPIRAL REINFORCEMENT.



STRESS-DEFORMATION CURVES FOR 1/4" SPIRAL REINFORCEMENT.



STRESS-DEFORMATION CURVES
FOR
3/8" SPIRAL REINFORCEMENT.



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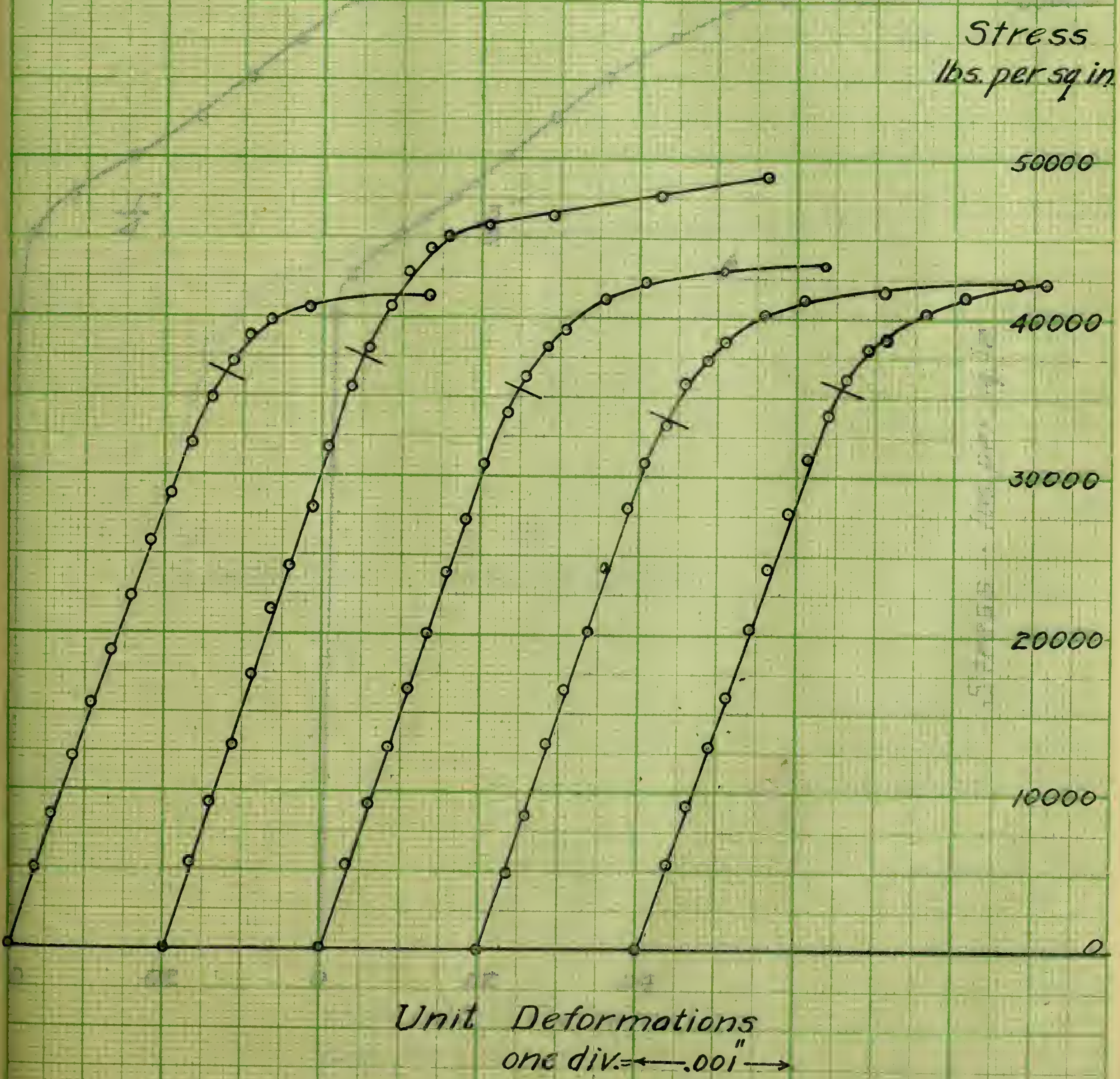
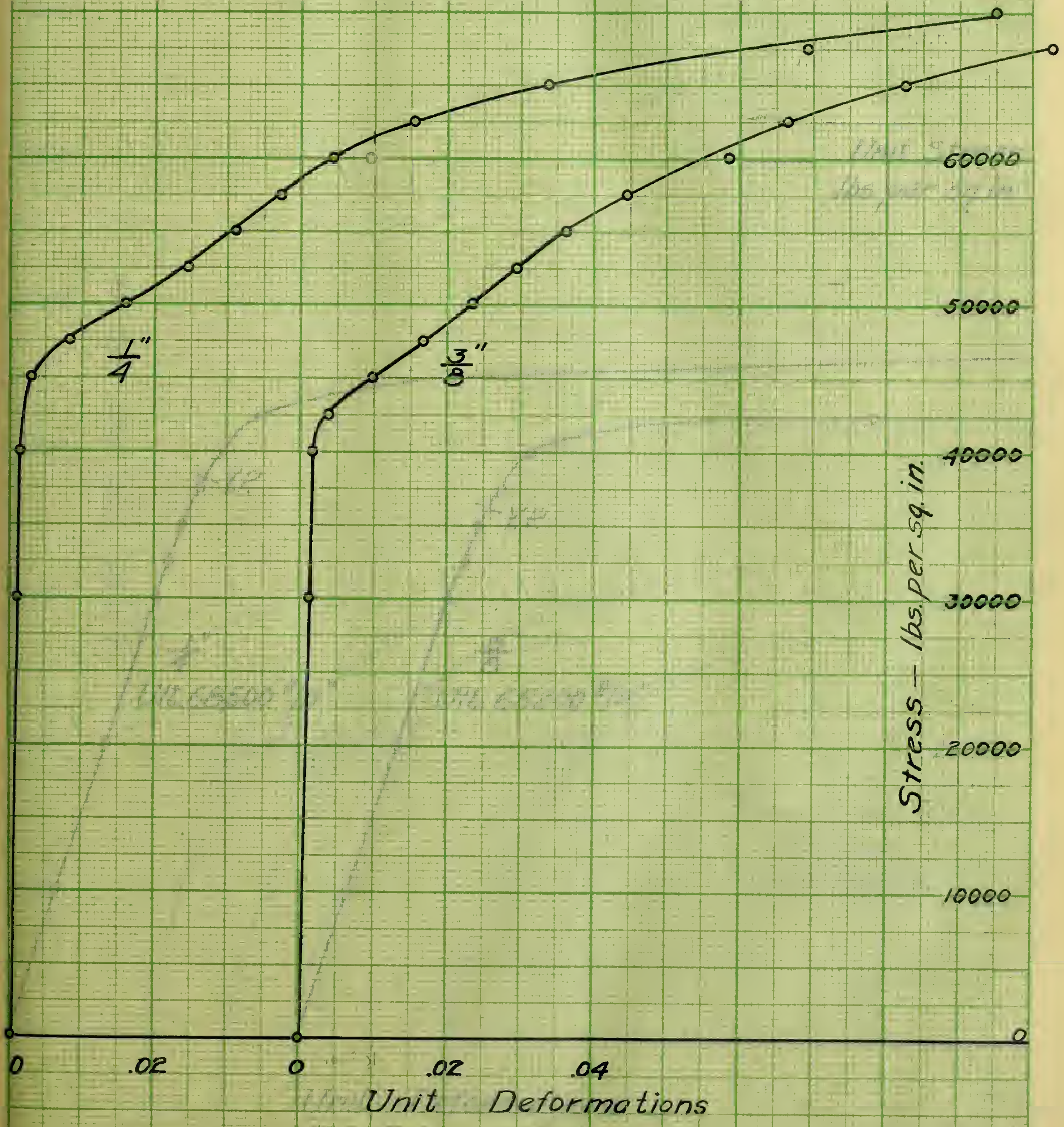
3/8" SPIRAL REINFORCEMENT.



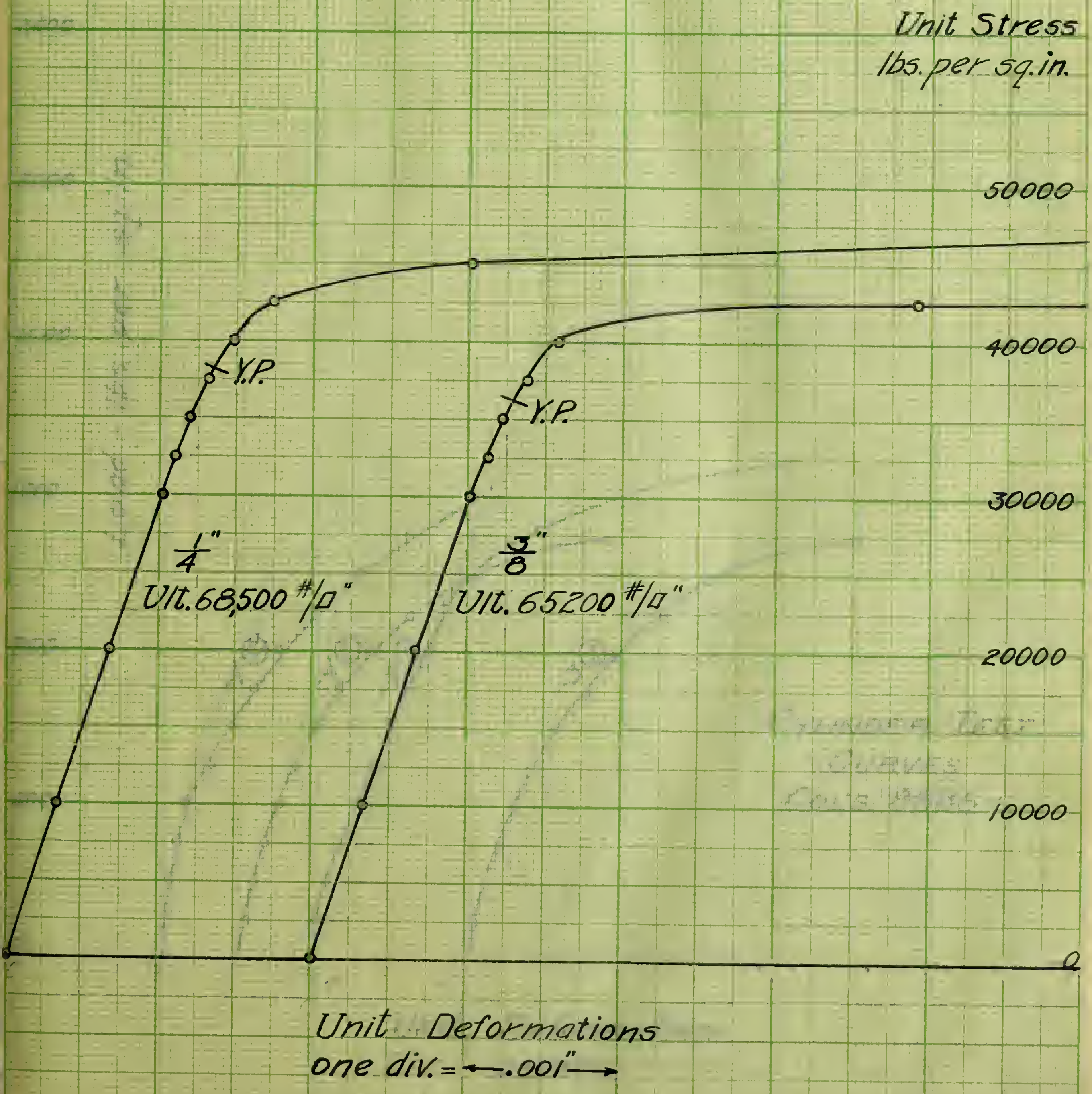
AVERAGE STRESS-DEFORMATION CURVES FOR SPIRAL REINFORCEMENT

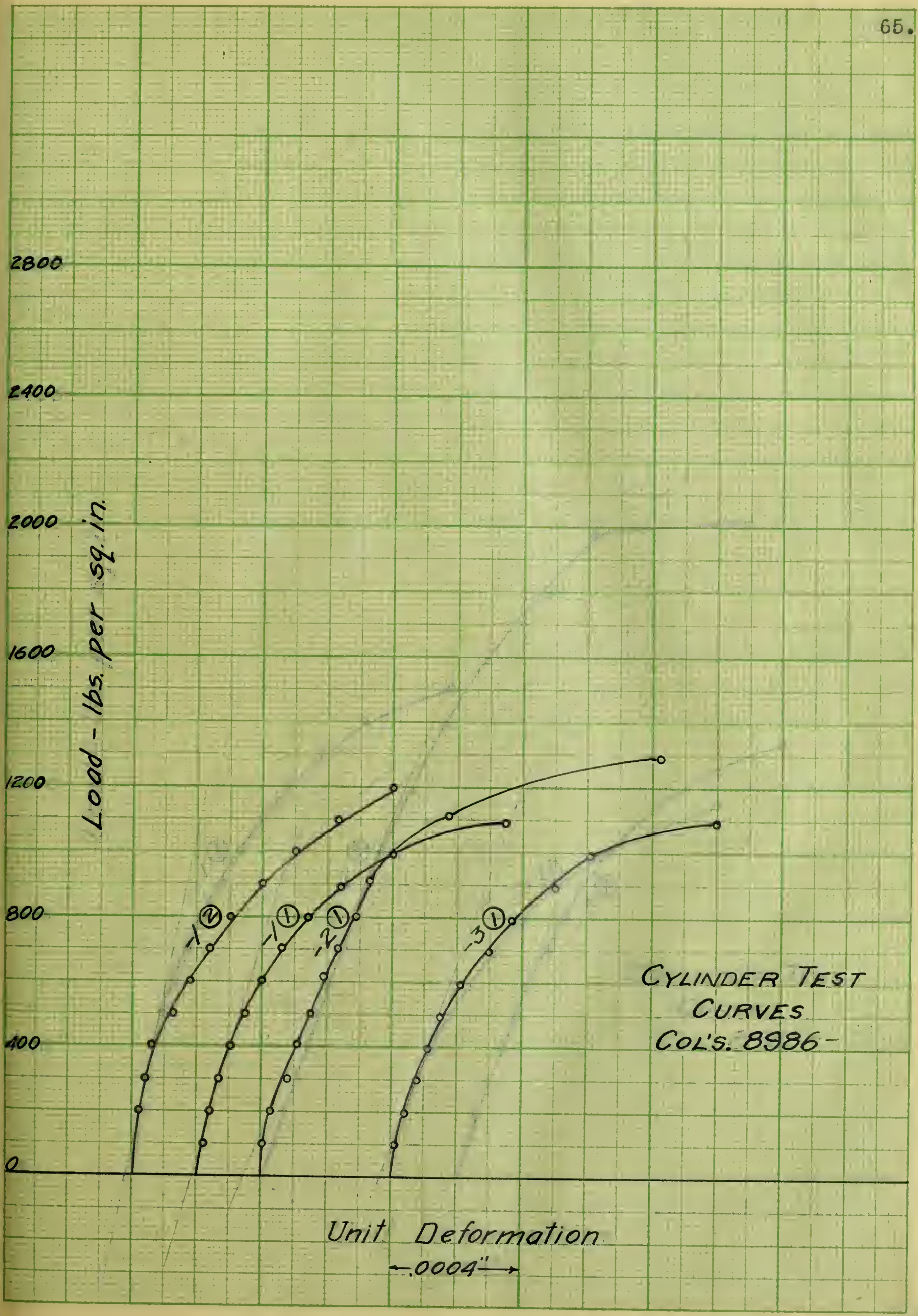
EACH CURVE IS AN AVERAGE OF NINE TESTS.



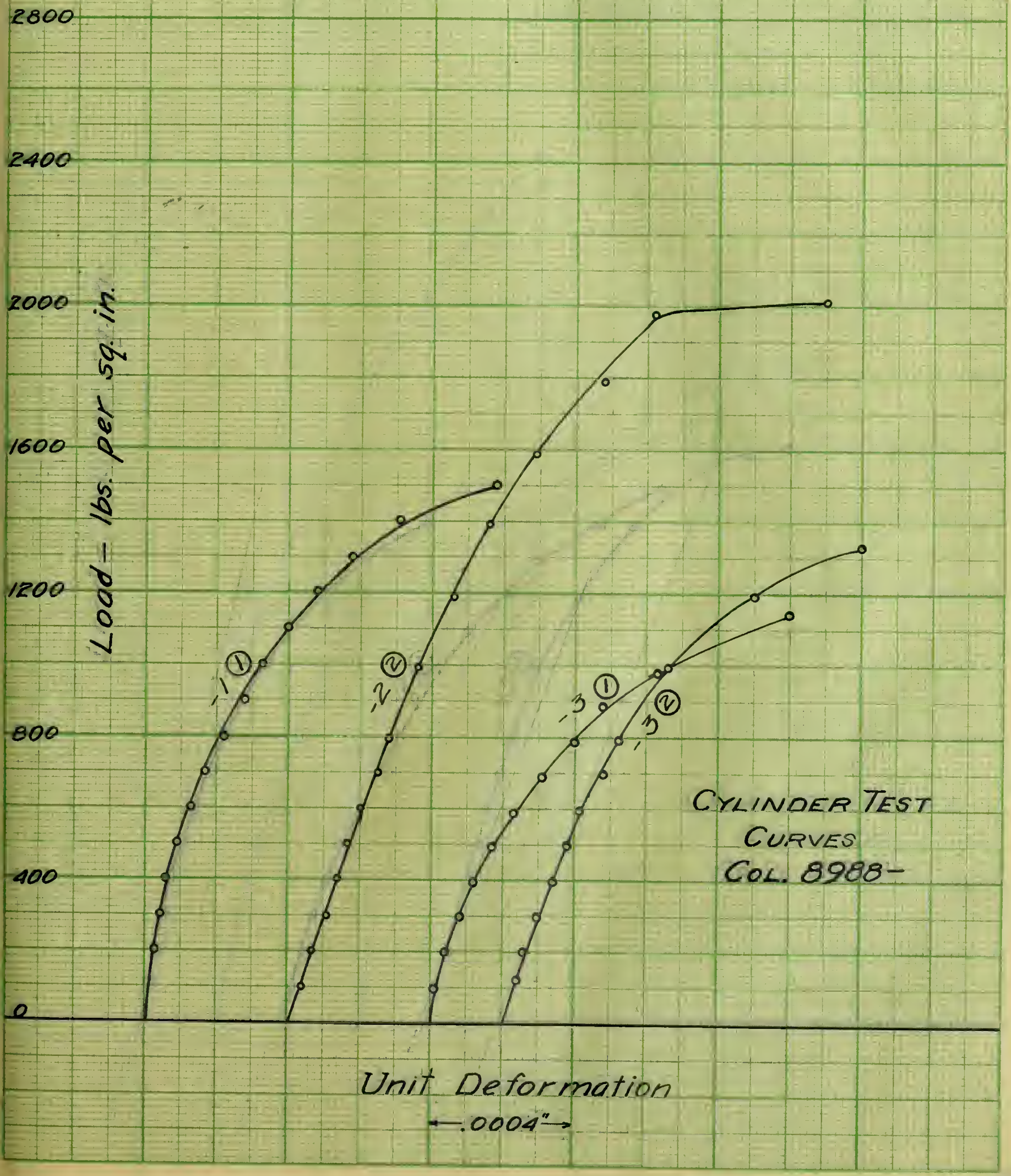
AVERAGE
STRESS-DEFORMATION CURVES
FOR
SPIRAL REINFORCEMENT.

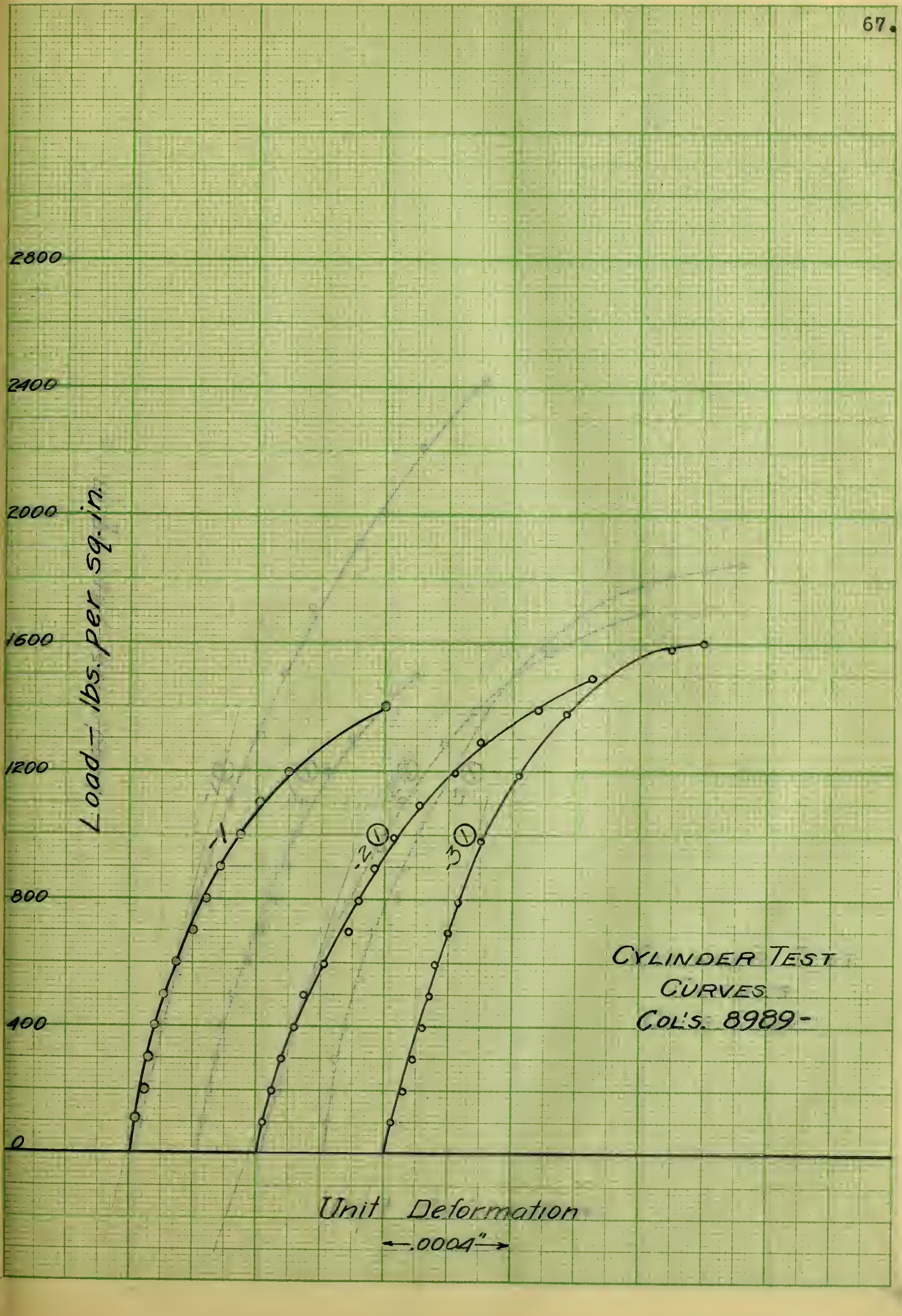
EACH CURVE IS AN AVERAGE OF NINE TESTS.

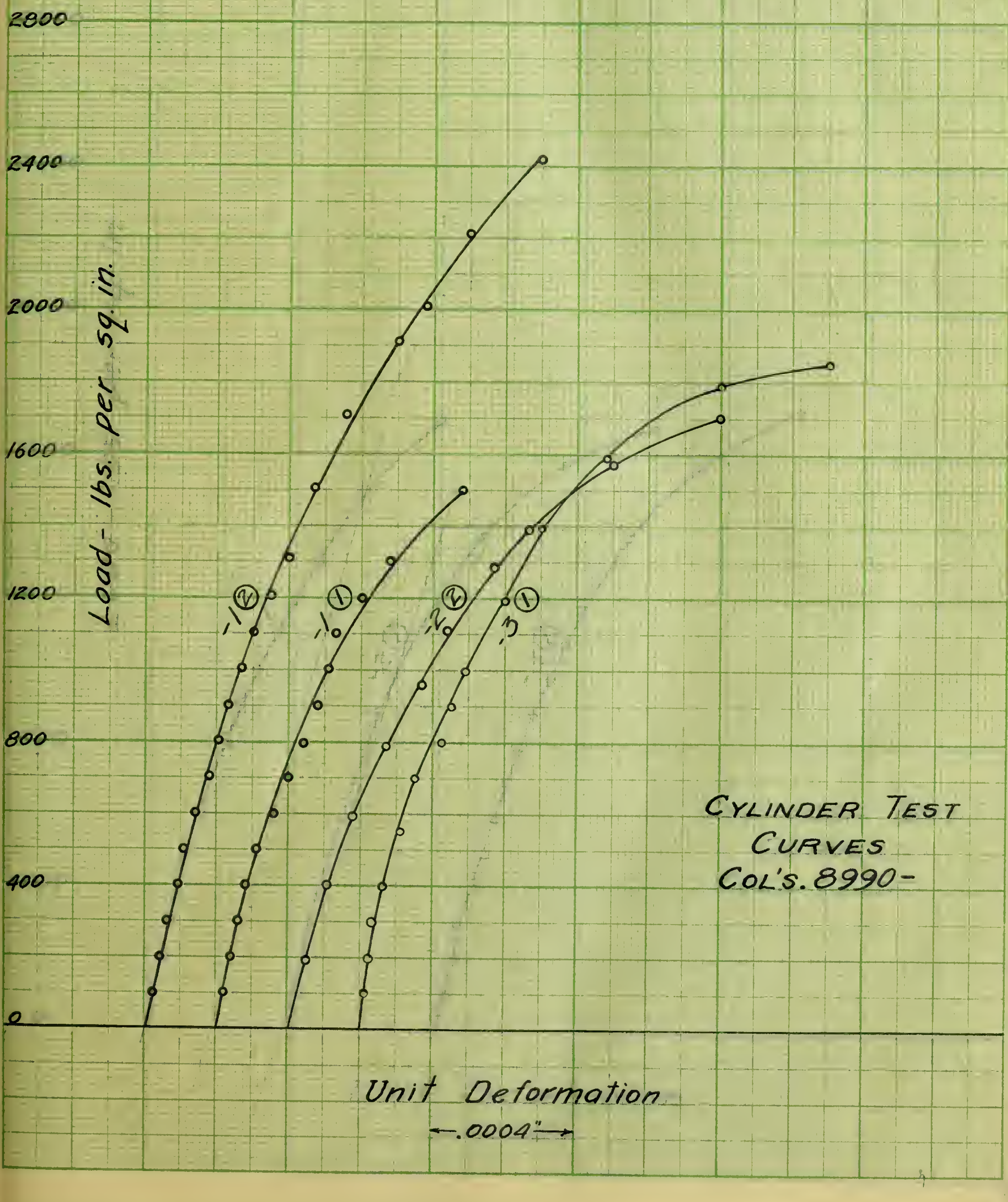


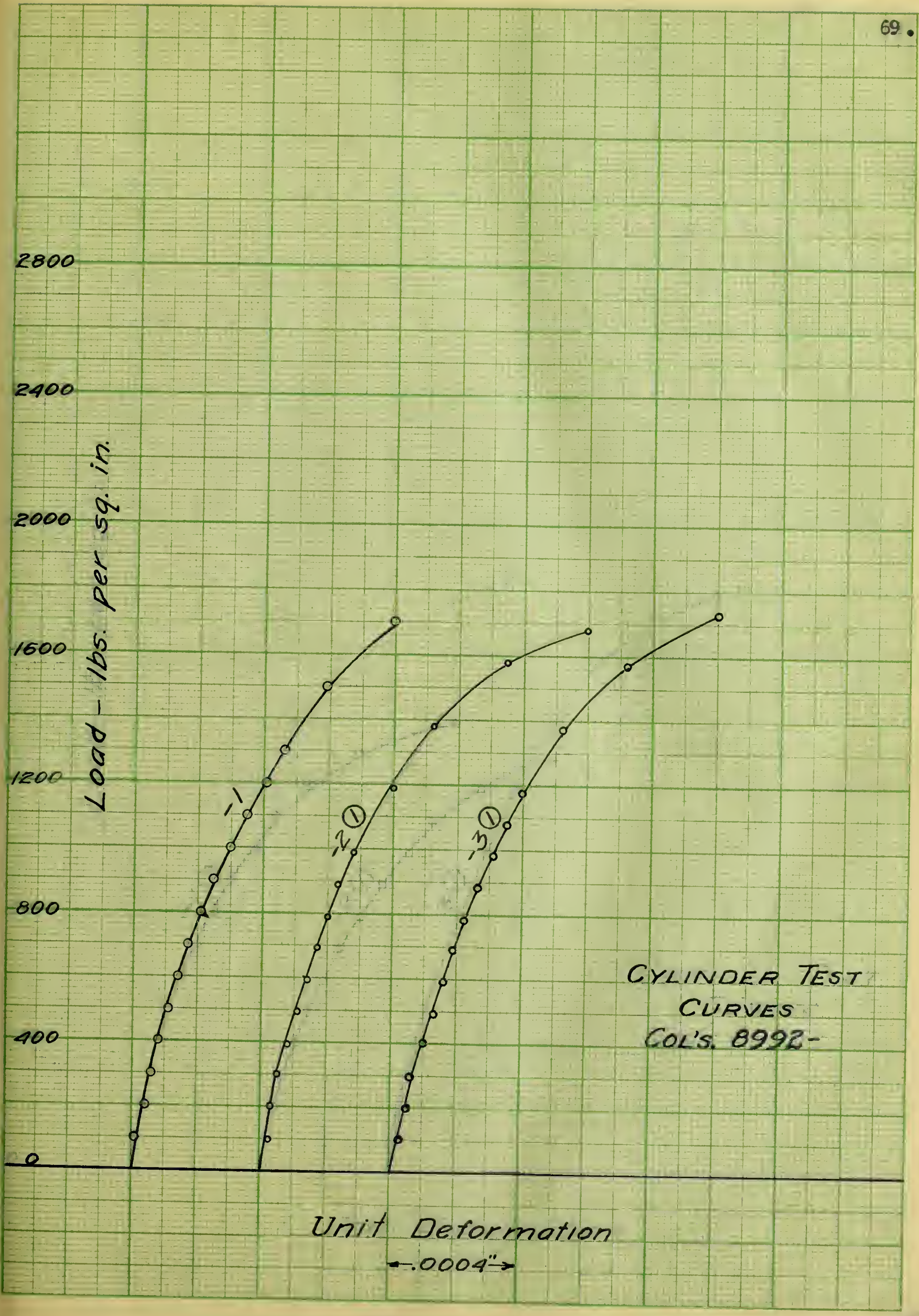


CYLINDER TEST
CURVES
COL'S. 8986-

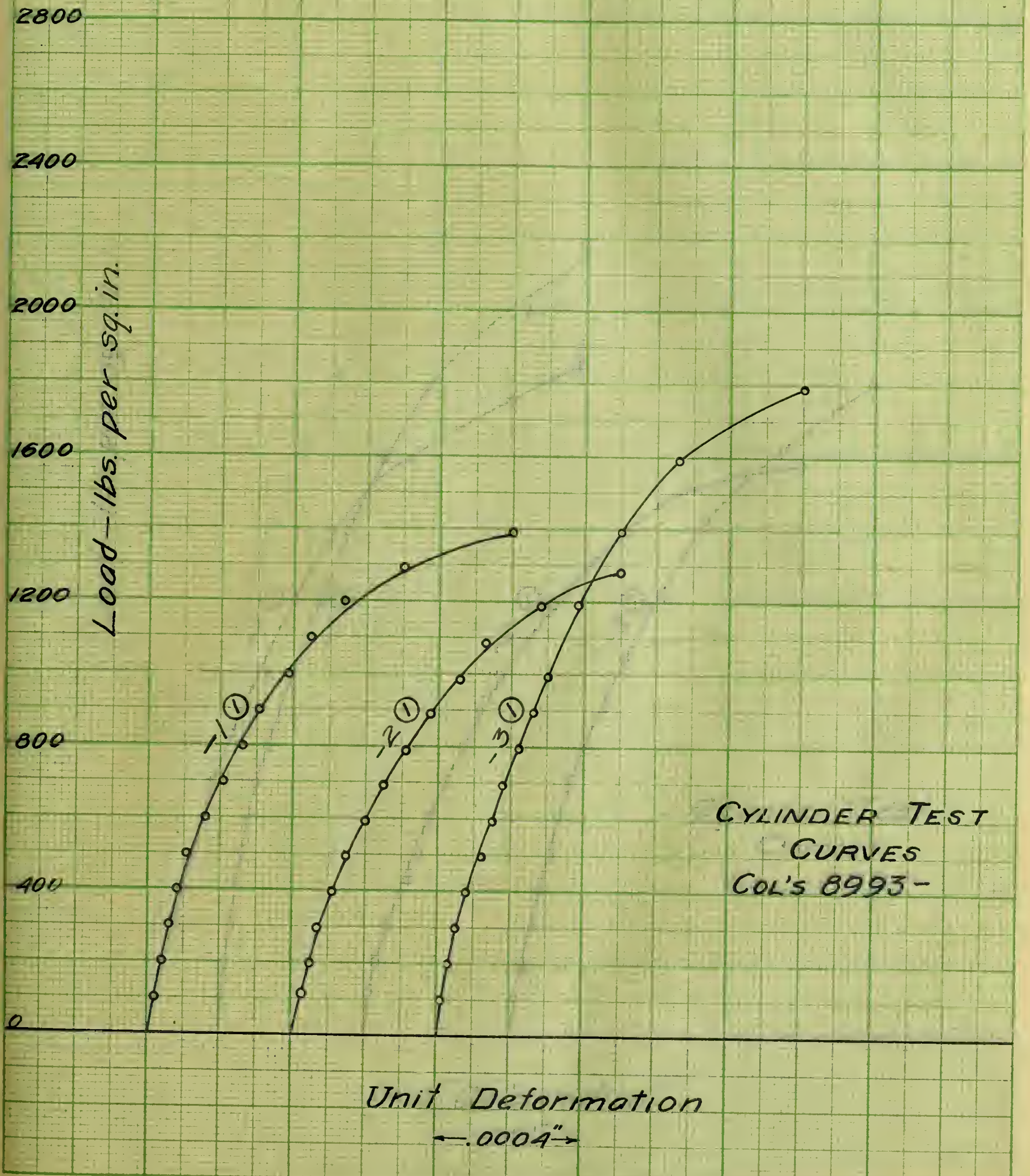

2800
2400
2000
1600
1200
800
400
0
Load - lbs. per sq. in.
-1 ①
-2 ②
-3 ①
-3 ②
CYLINDER TEST
CURVES
COL. 8988-
Unit Deformation
←.0004"→


2800
2400
2000
1600
1200
800
400
0
Load – lbs. per sq. in.
1
2 ①
3 ①
Unit Deformation
←.0004"→
CYLINDER TEST
CURVES.
COL'S. 8989-


2800
2400
2000
1600
1200
800
400
0
Load - lbs. per sq. in.
.1②
.1①
.2②
.3①
Unit Deformation
←.0004"→
CYLINDER TEST
CURVES
COL'S. 8990-



CYLINDER TEST CURVES
COL'S. 8992-



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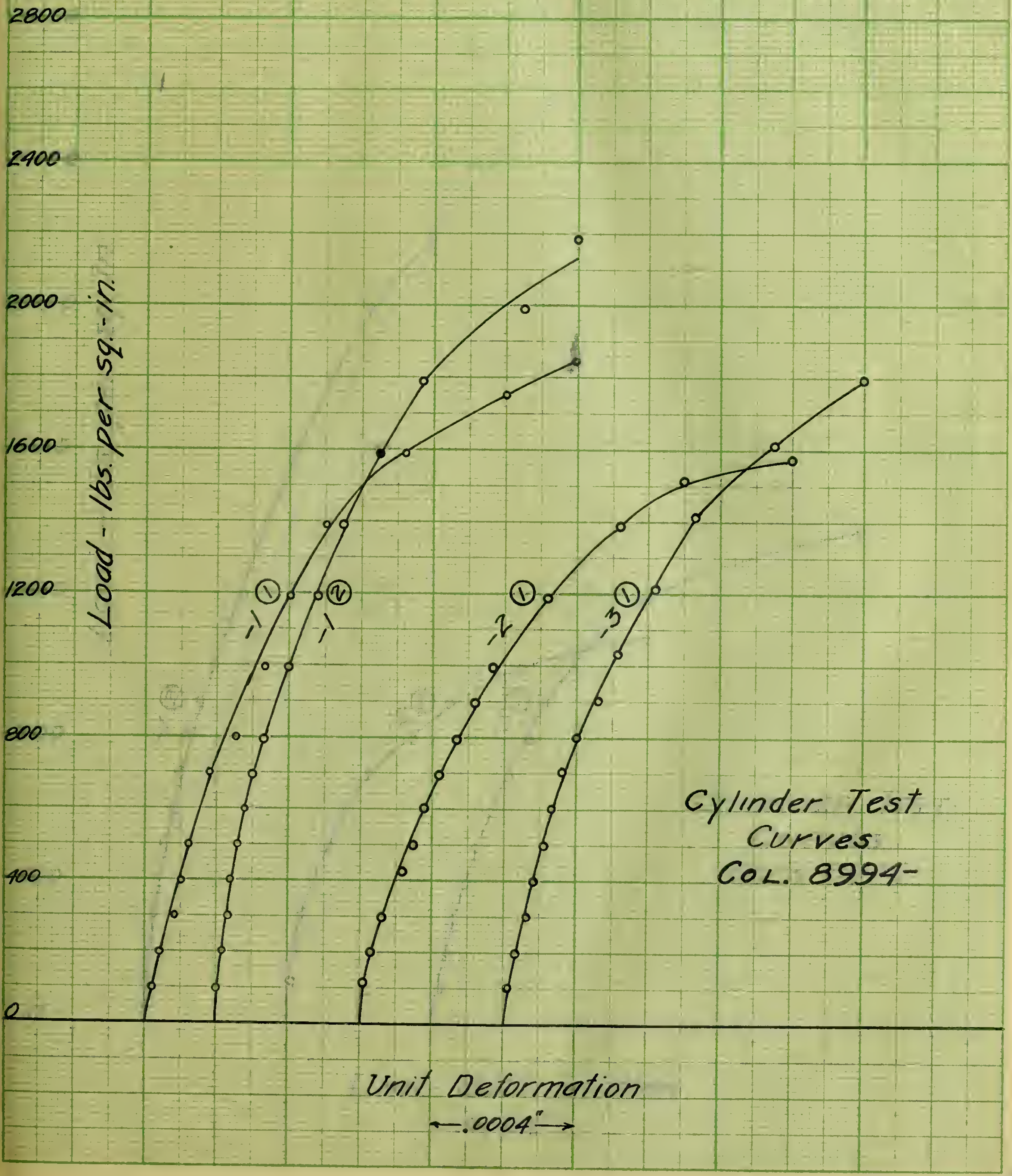
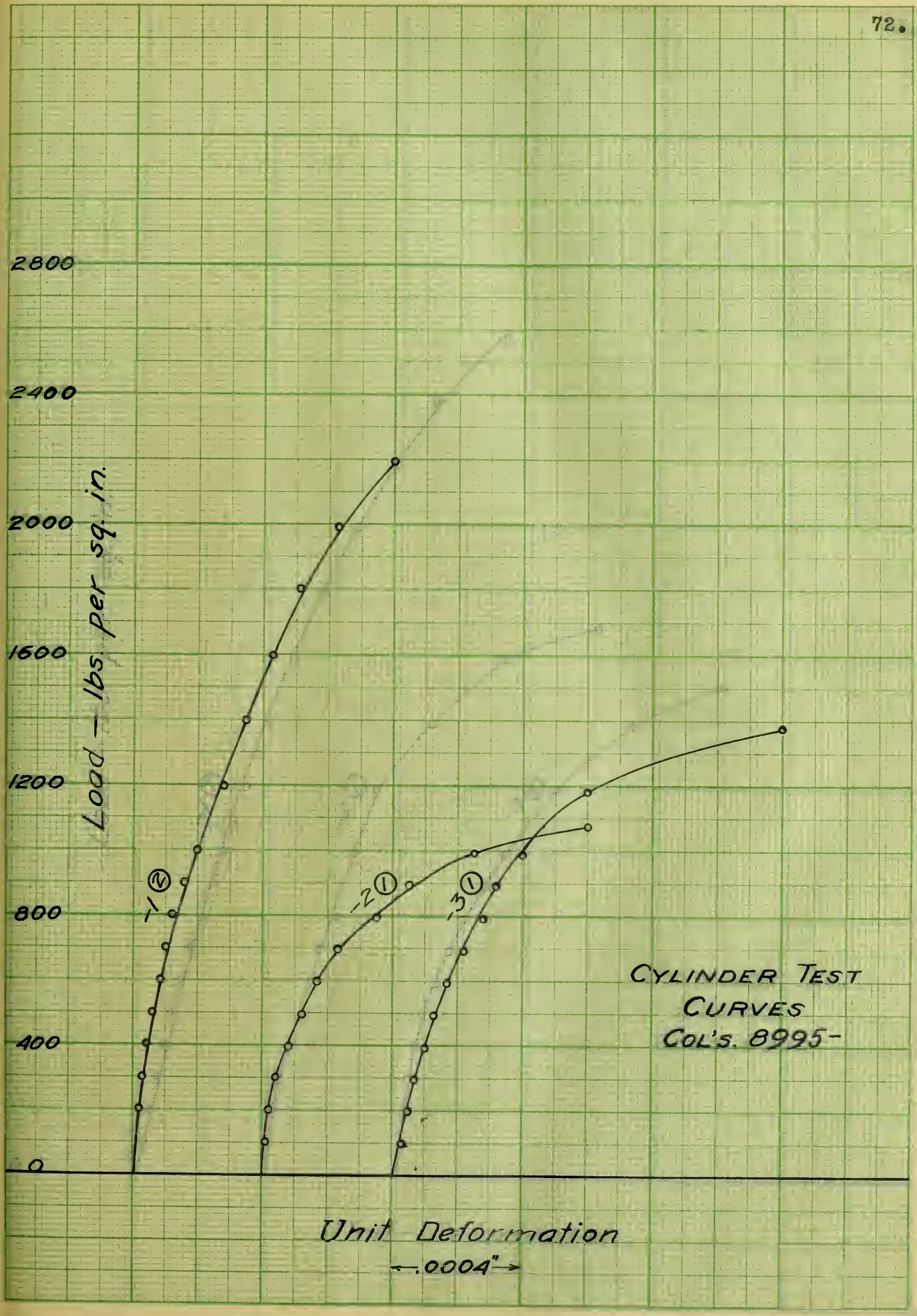
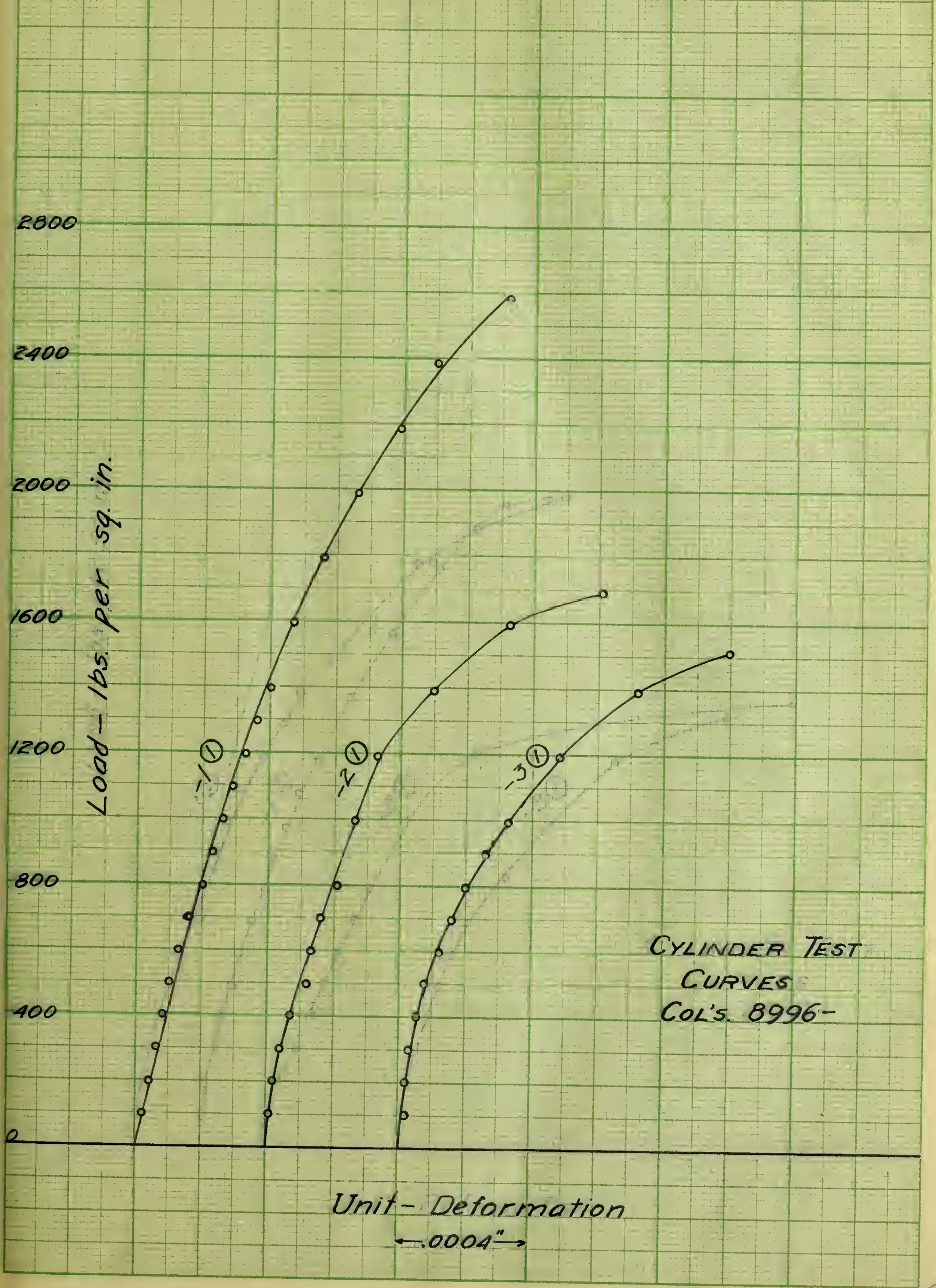
CURVES
COL'S 8993-



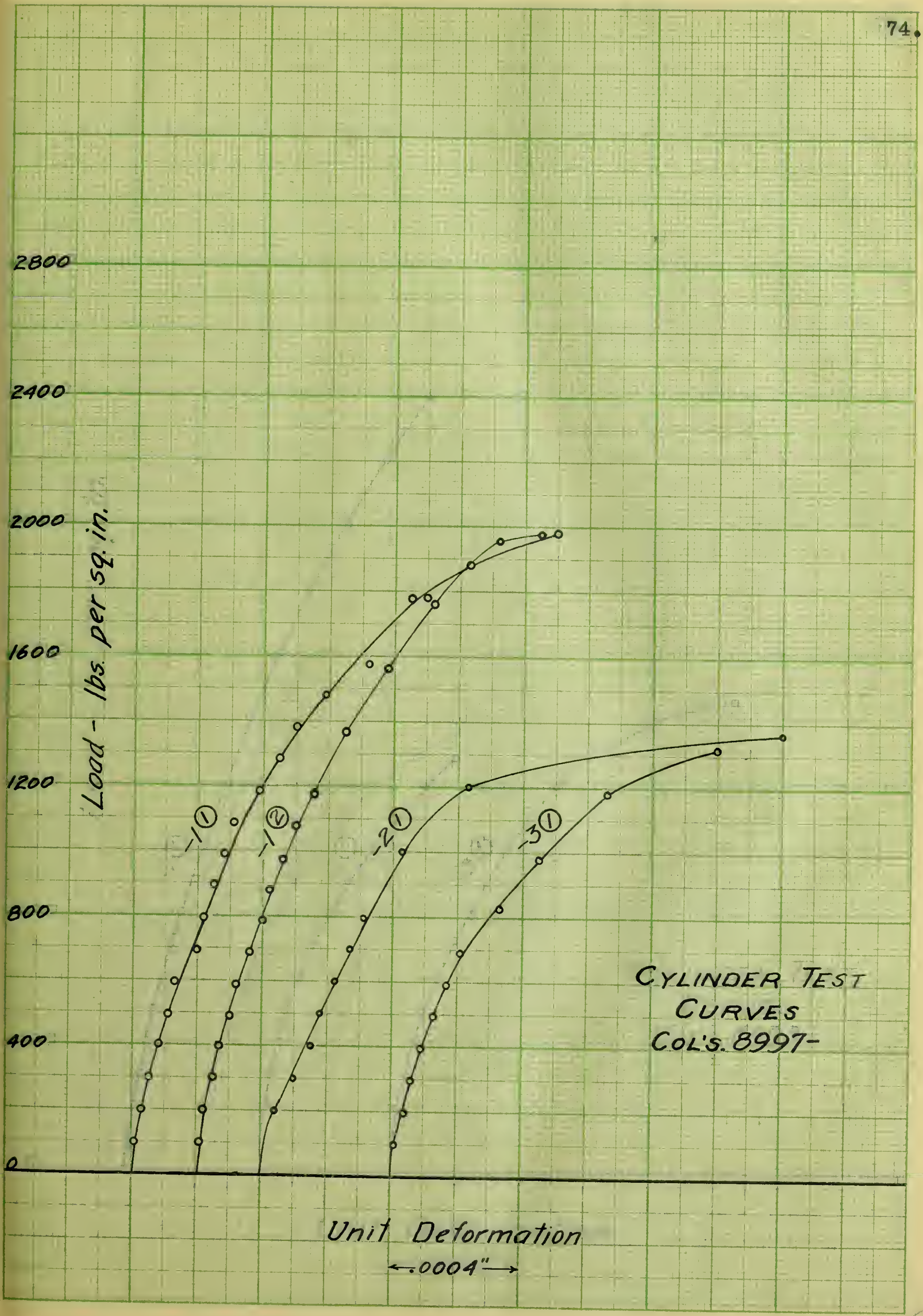
Cylinder Test
Curves
Col. 8994-

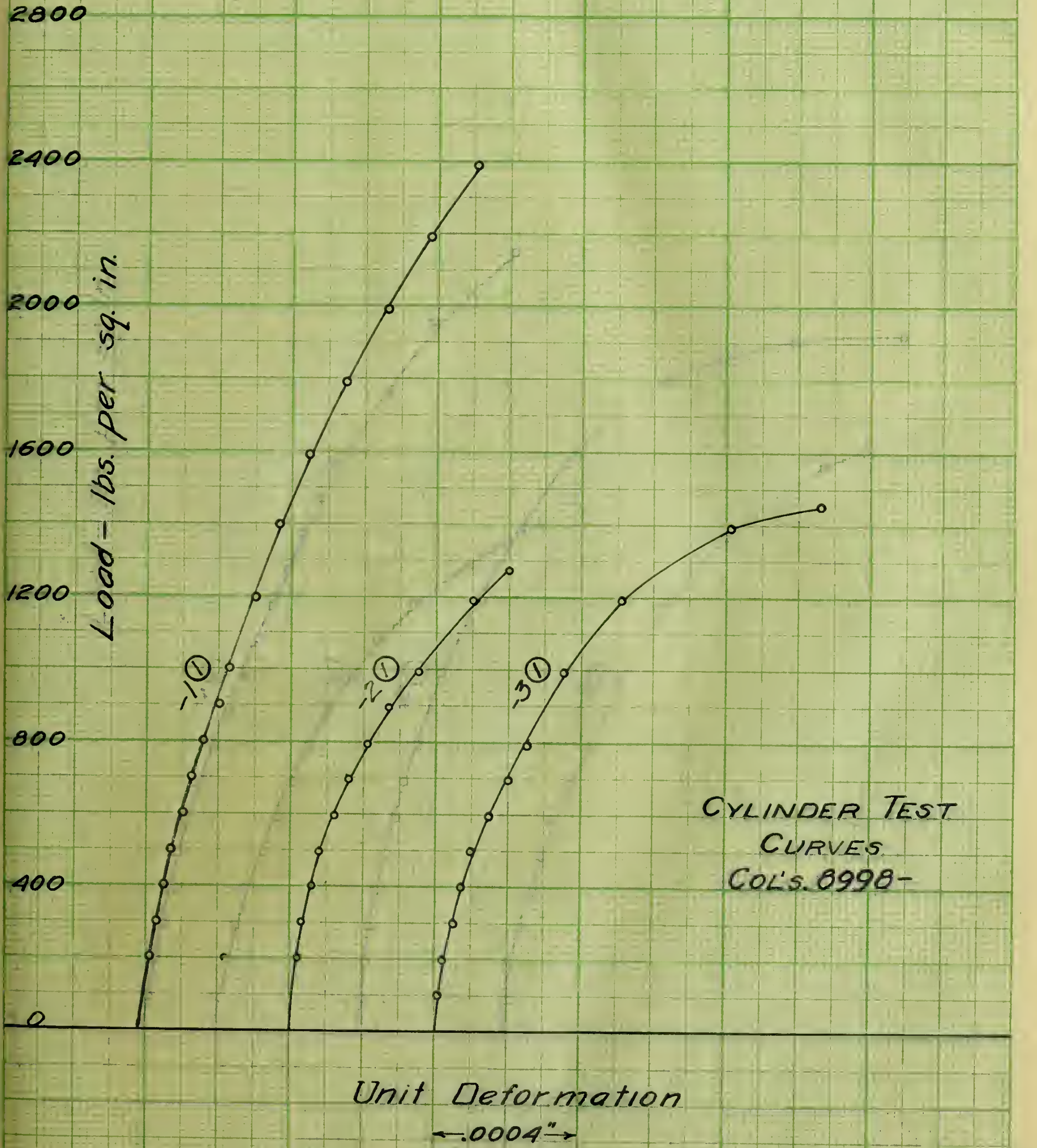

2800
2400
2000
1600
1200
800
400
0
Load – lbs. per sq. in.
-1 ②
-2 ①
-3 ①
CYLINDER TEST
CURVES
COL'S. 8995-
Unit Deformation
←.0004"→

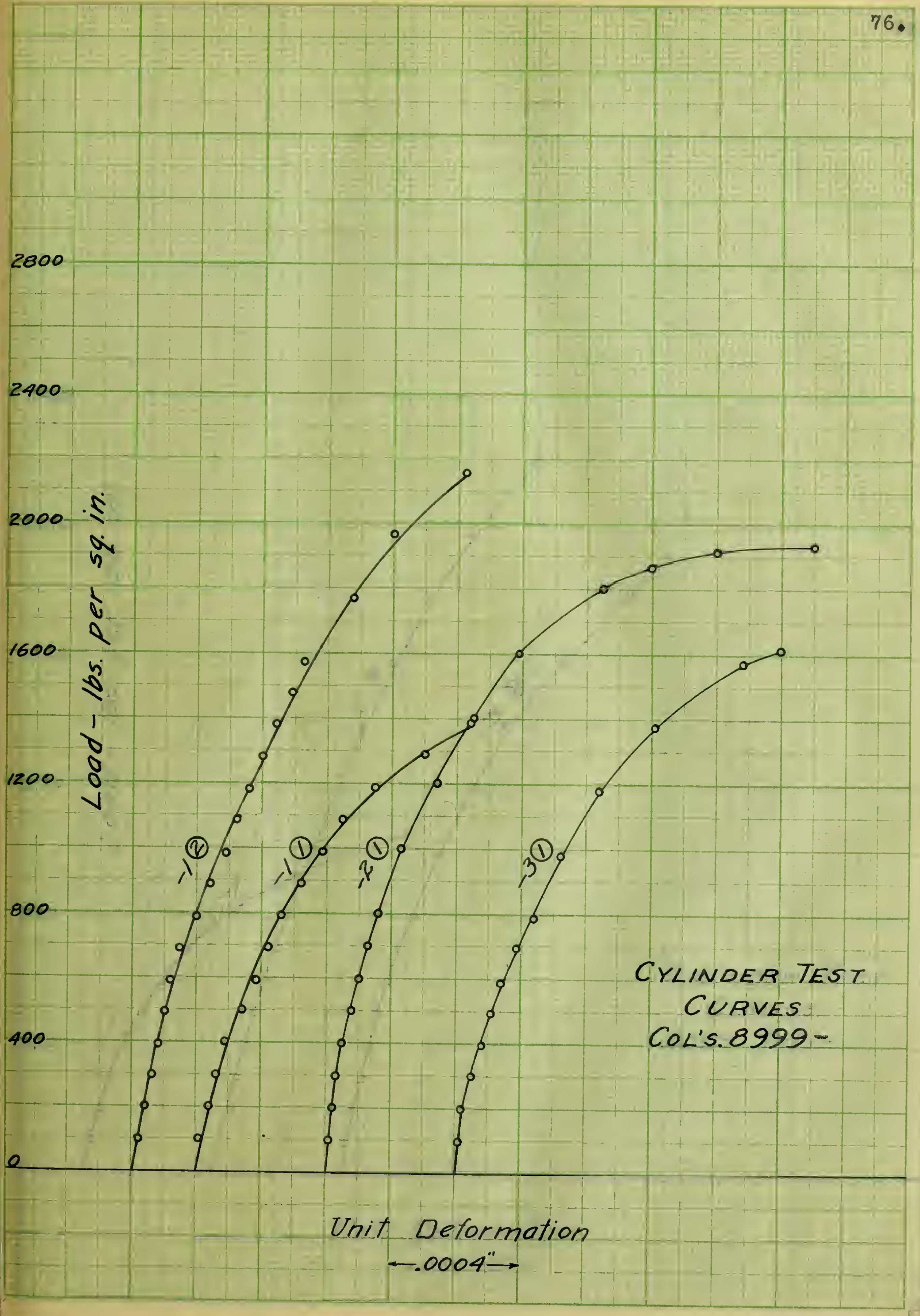


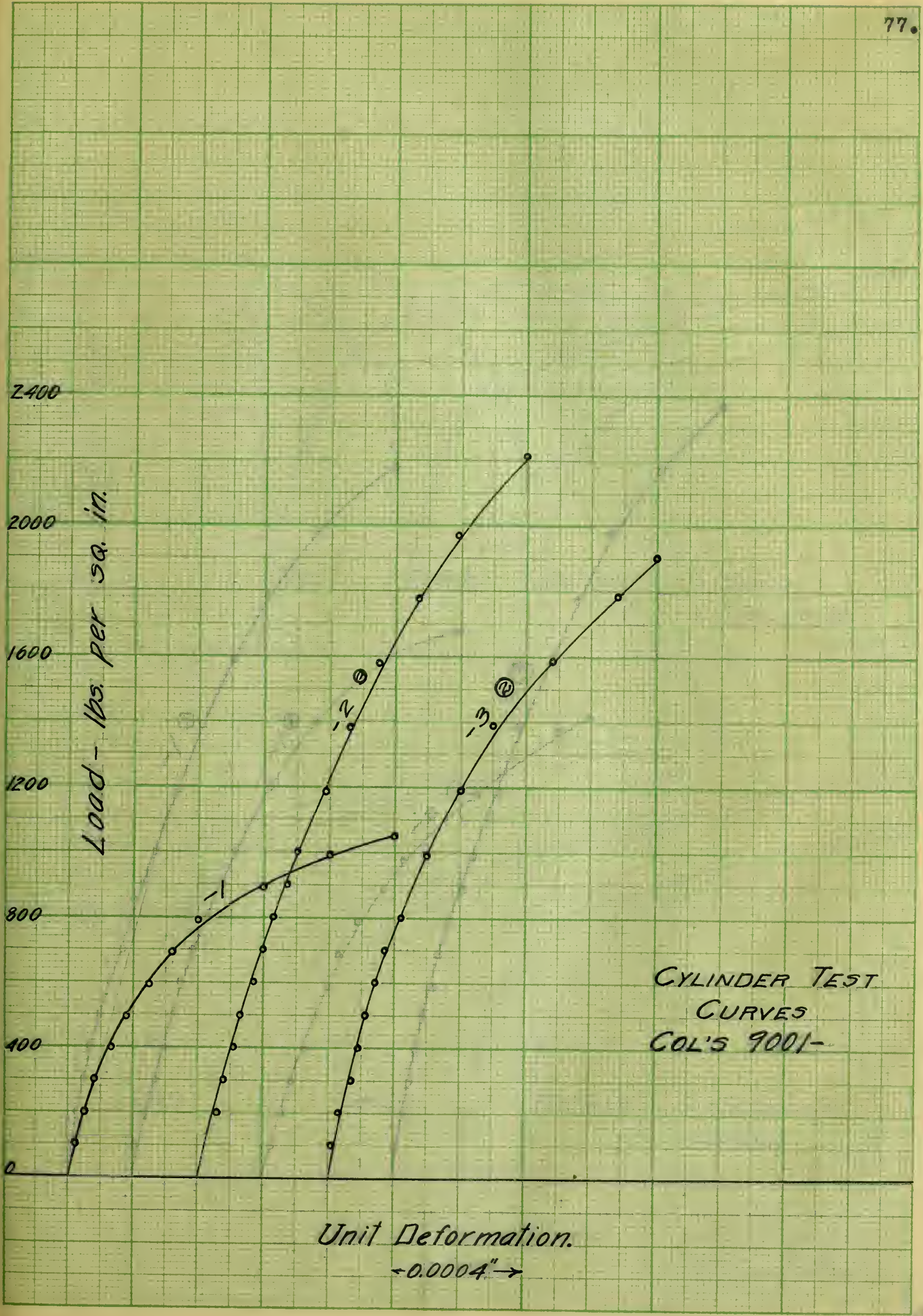
CYLINDER TEST CURVES
COL'S. 8996-

a

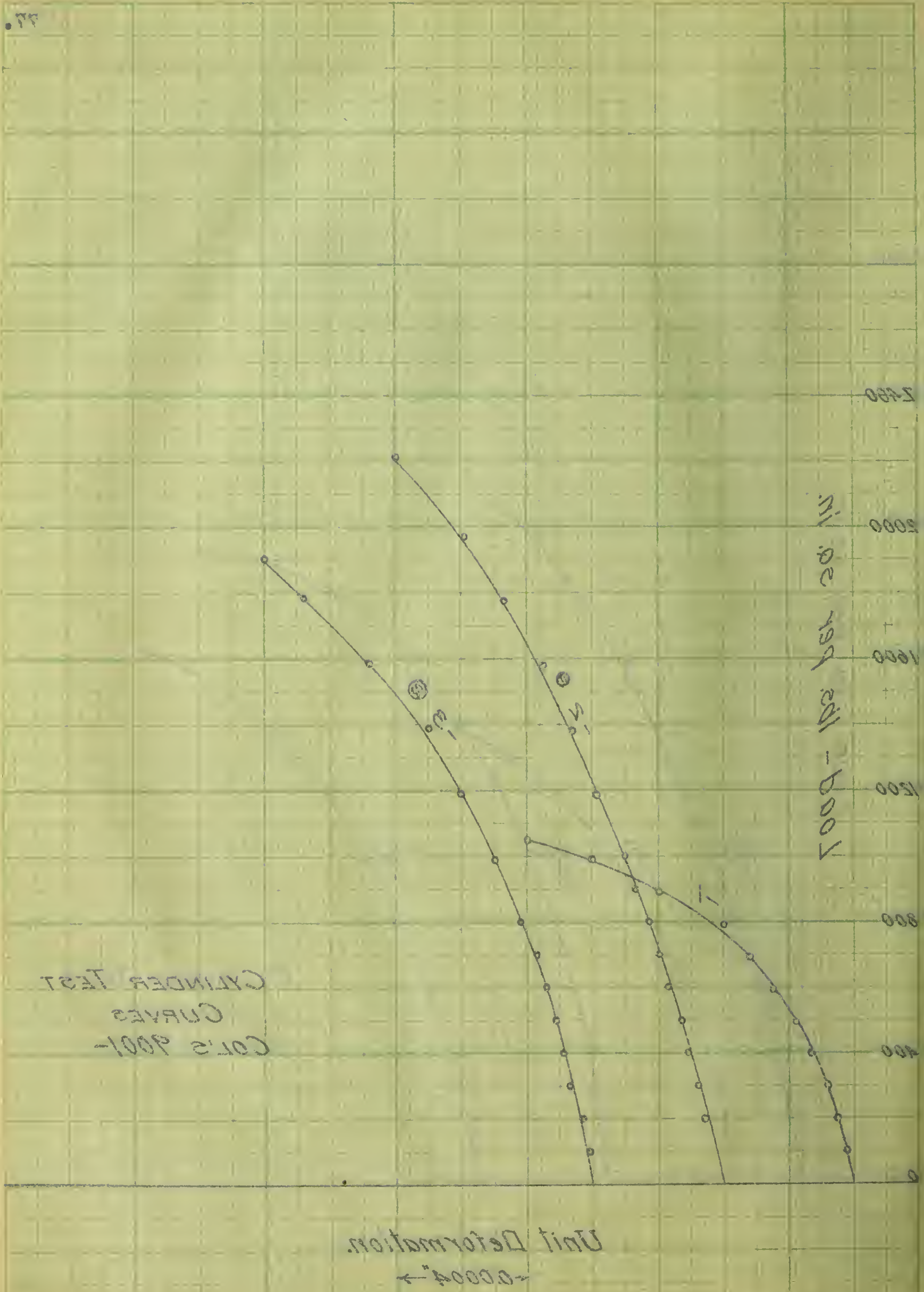

2800
2400
2000
1600
1200
800
400
0
Load - lbs. per sq. in.
-1①
-1②
-2①
-3①
CYLINDER TEST
CURVES
COL'S. 8997-
Unit Deformation
←.0004"→

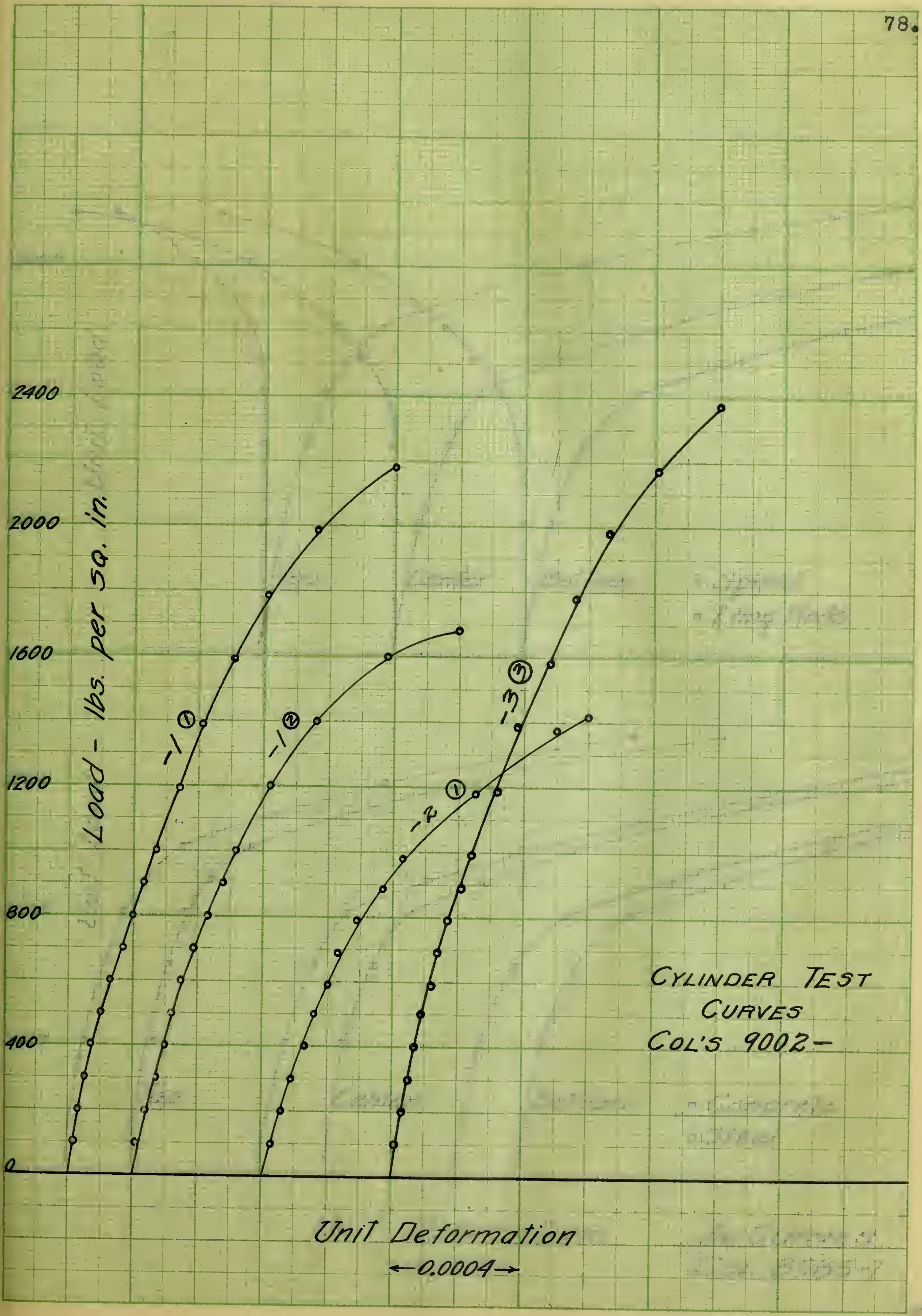

2800
2400
2000
1600
1200
800
400
0
Load - lbs. per sq. in.
-1①
-2①
-3①
Unit Deformation
←.0004"→
CYLINDER TEST
CURVES
COL'S. 8998-


2800
2400
2000
1600
1200
800
400
0
Load - lbs. per sq. in.
-1 ②
-1 ①
-2 ①
-3 ①
CYLINDER TEST
CURVES
COL'S. 8999-
Unit Deformation
←.0004"→

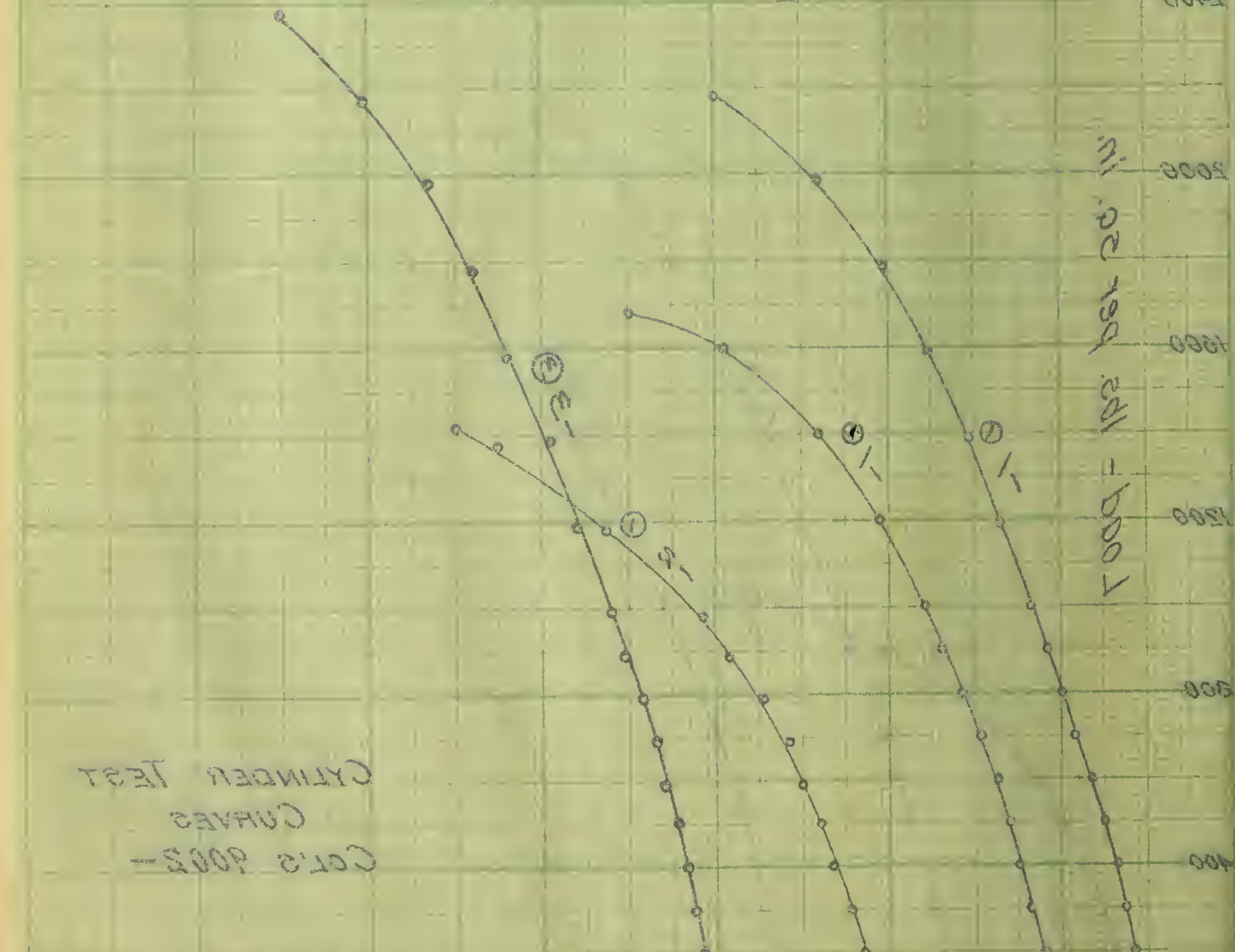


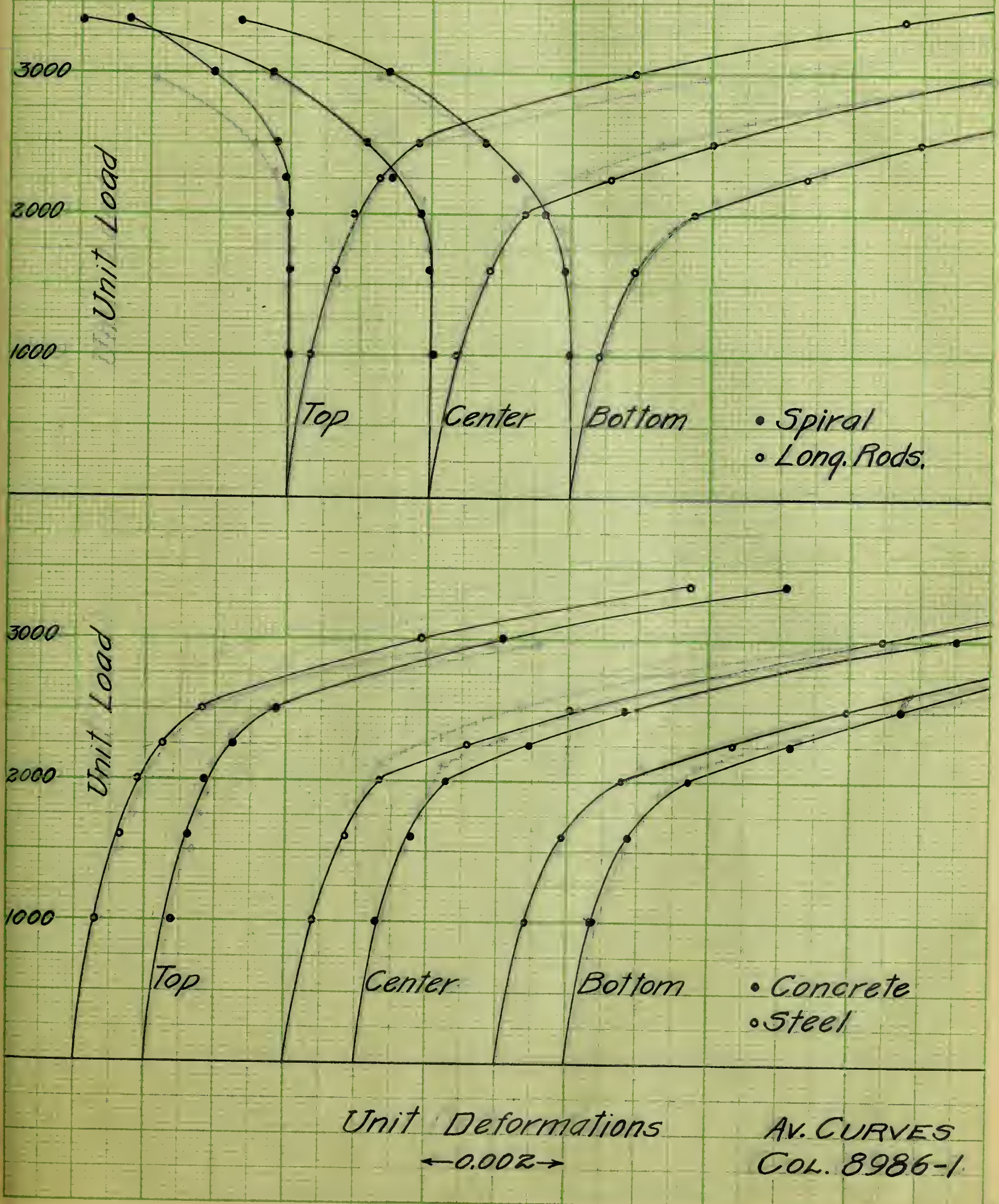
CYLINDER TEST
CURVES
COL'S 9001-

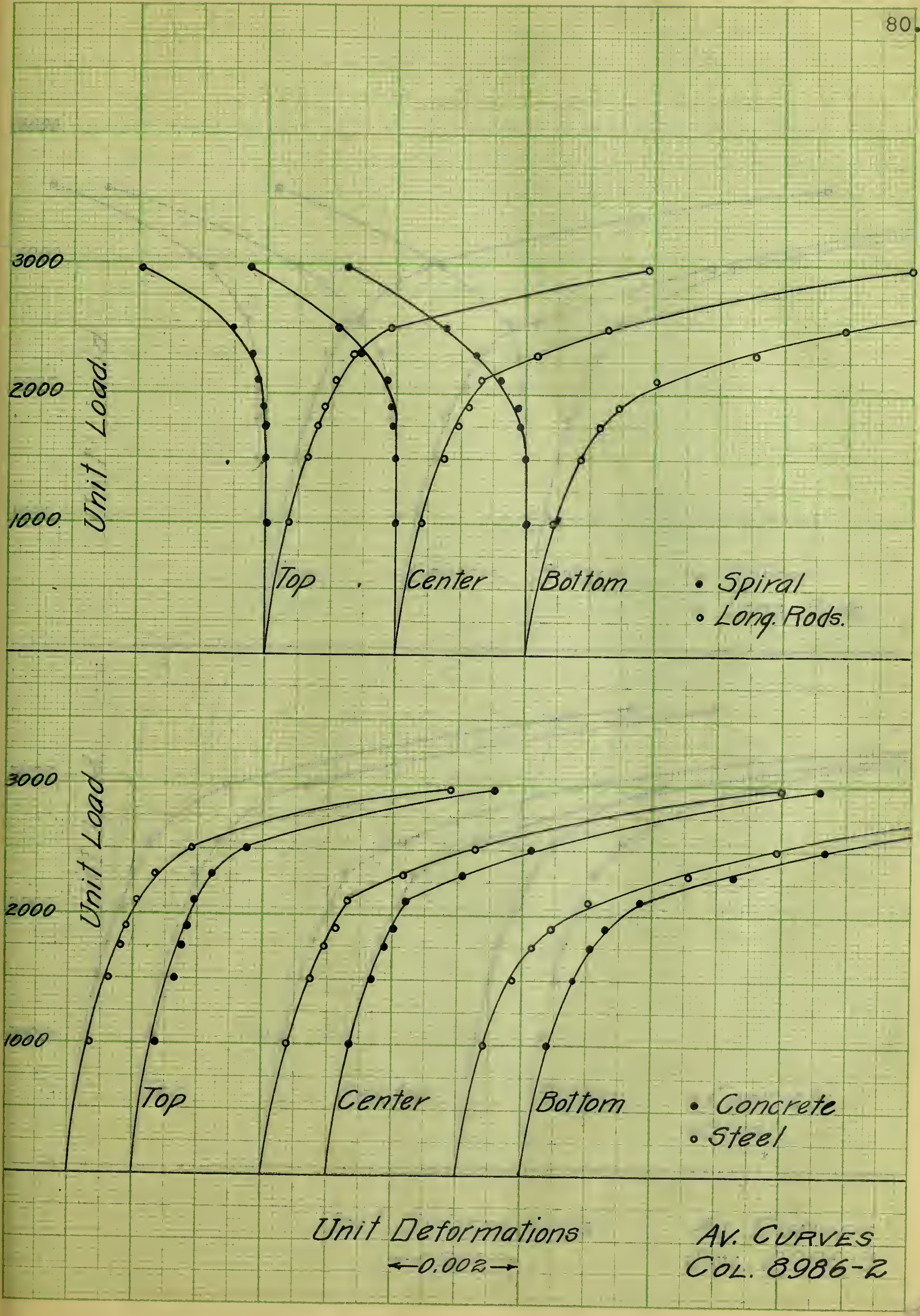

77.
CYLINDER TEST
CURVES
COL.'S 1901-
Load - lbs. per sq. in.
2400
2000
1600
1200
800
400
0
①
②
-1
-2
-3
Unit Deformation.
←0.0004"→

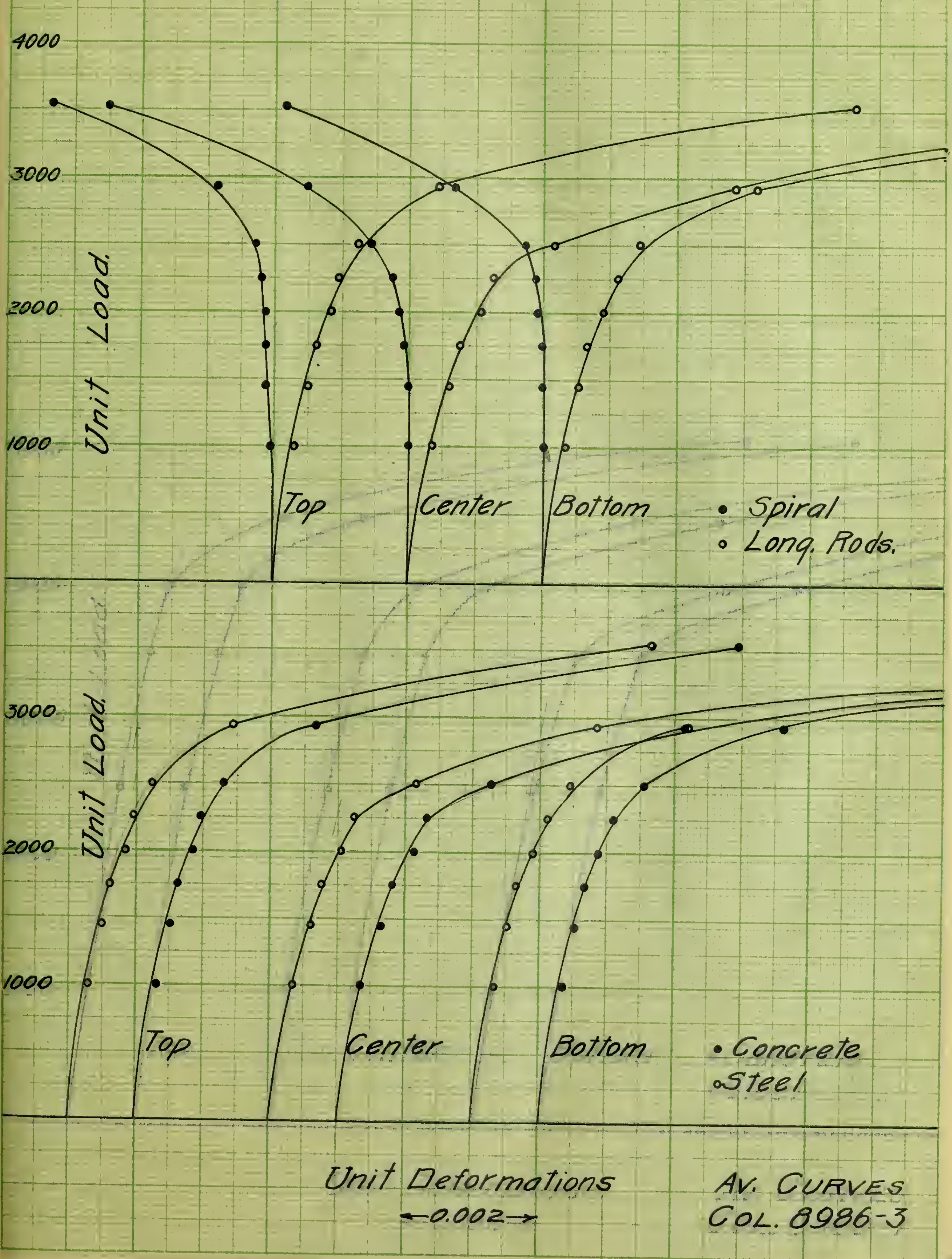


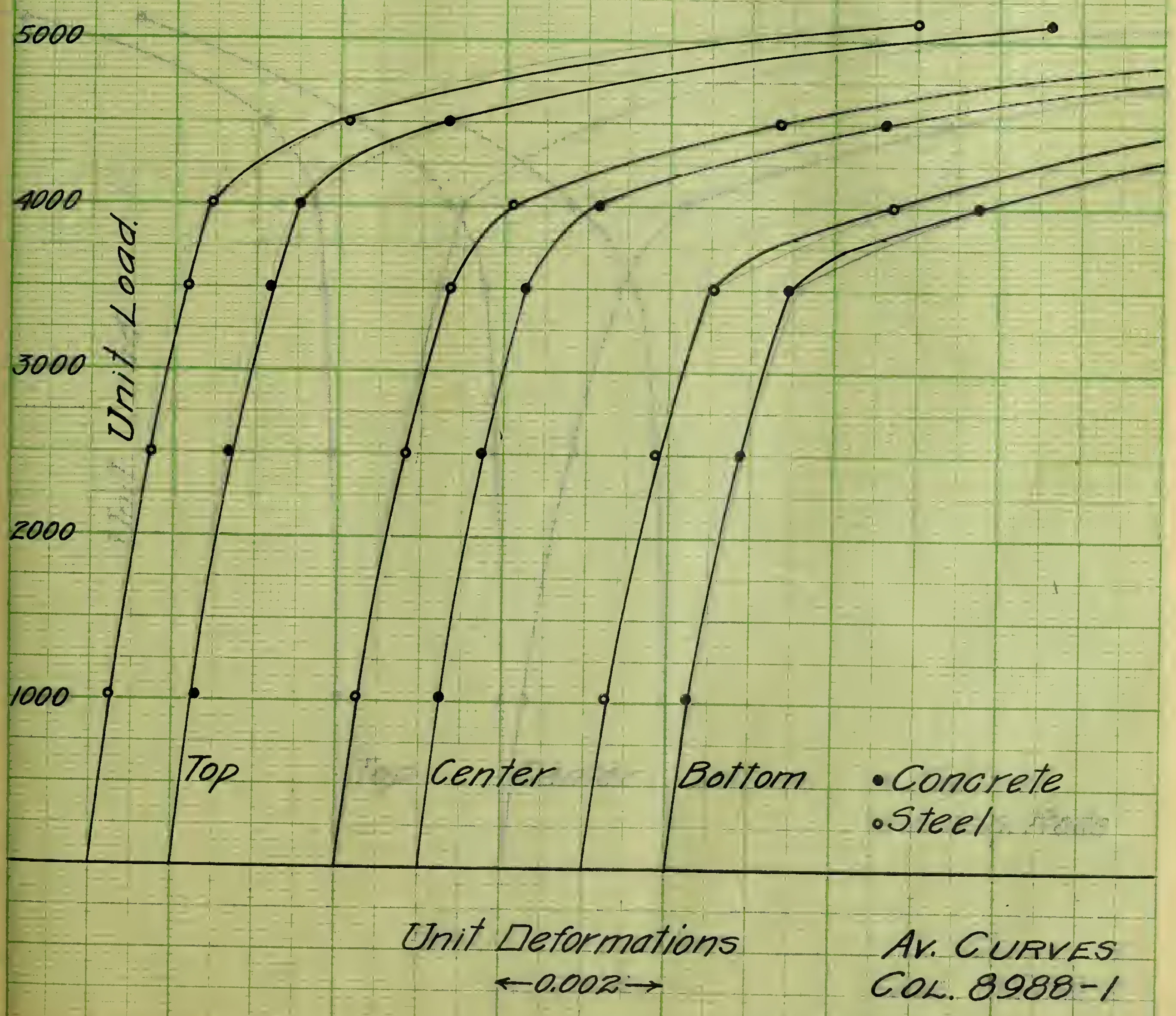
CYLINDER TEST
CURVES
COL'S 9002-



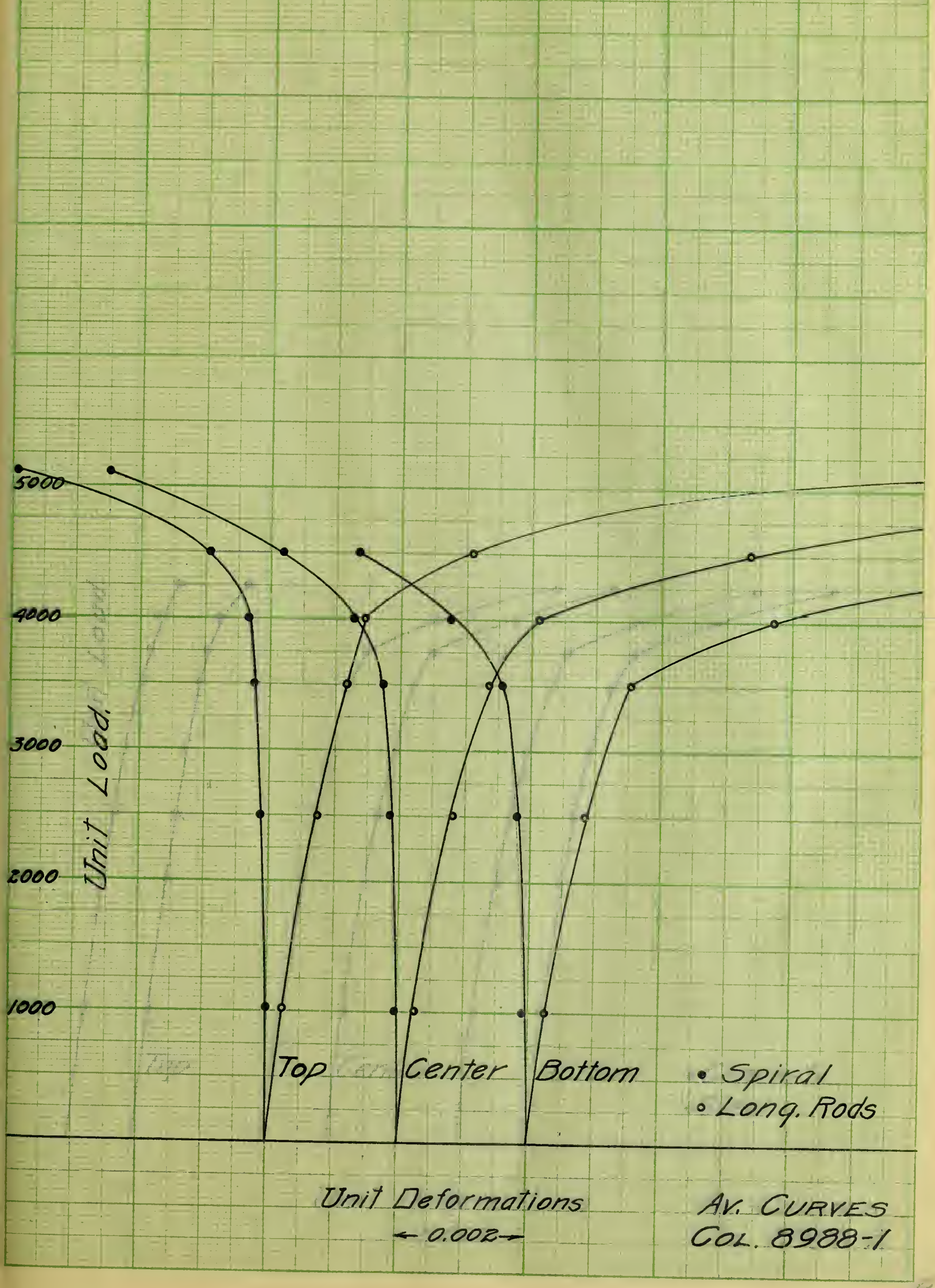

3000
2000
1000
Unit Load
Top
Center
Bottom
• Spiral
∘ Long. Rods.
3000
2000
1000
Unit Load
Top
Center
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8986-1


3000
2000
1000
Unit Load.
Top
Center
Bottom
• Spiral
∘ Long. Rods.
3000
2000
1000
Unit Load
Top
Center
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
AV. CURVES
COL. 8986-2

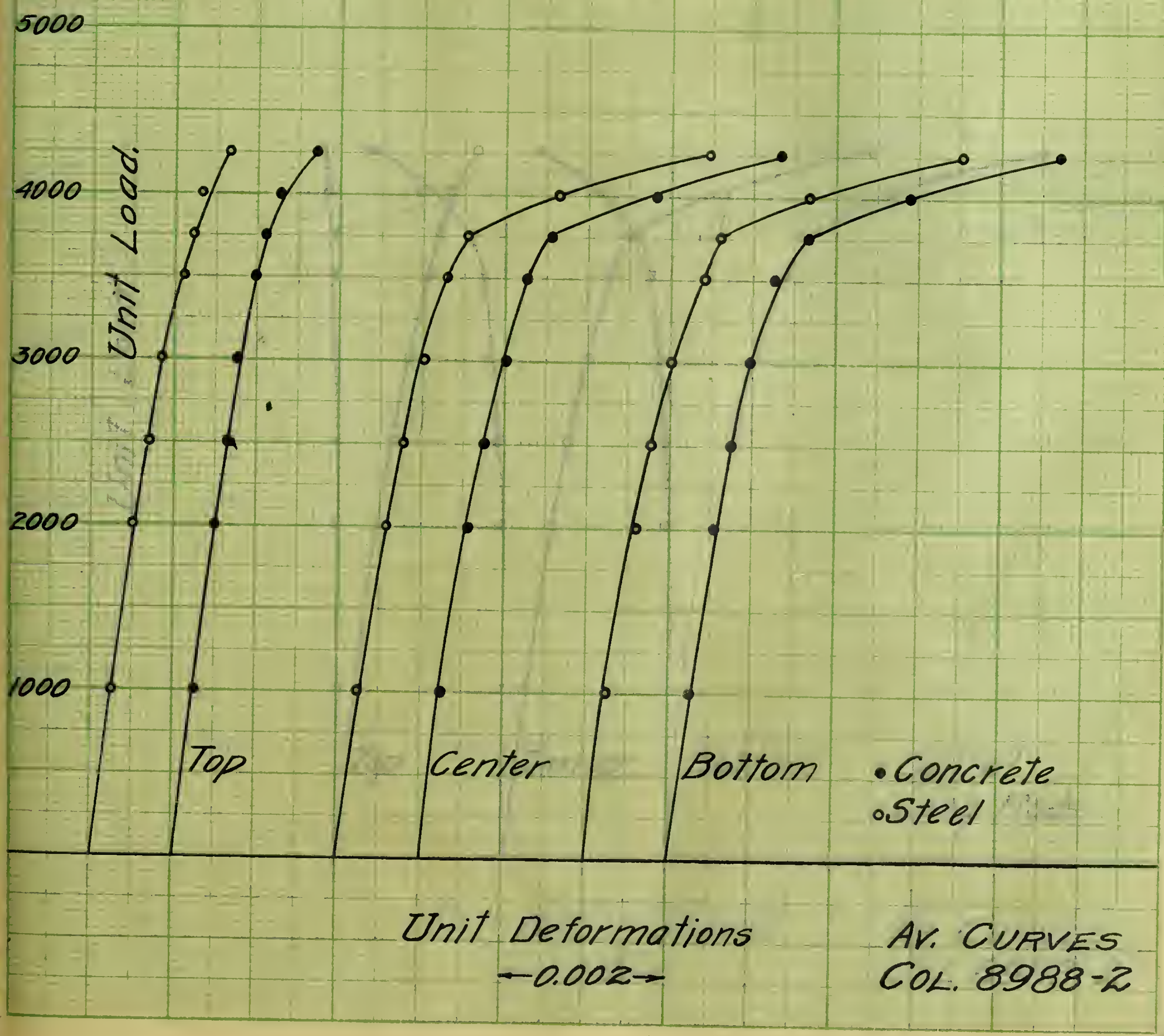

4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Spiral
∘ Long. Rods.
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8986-3

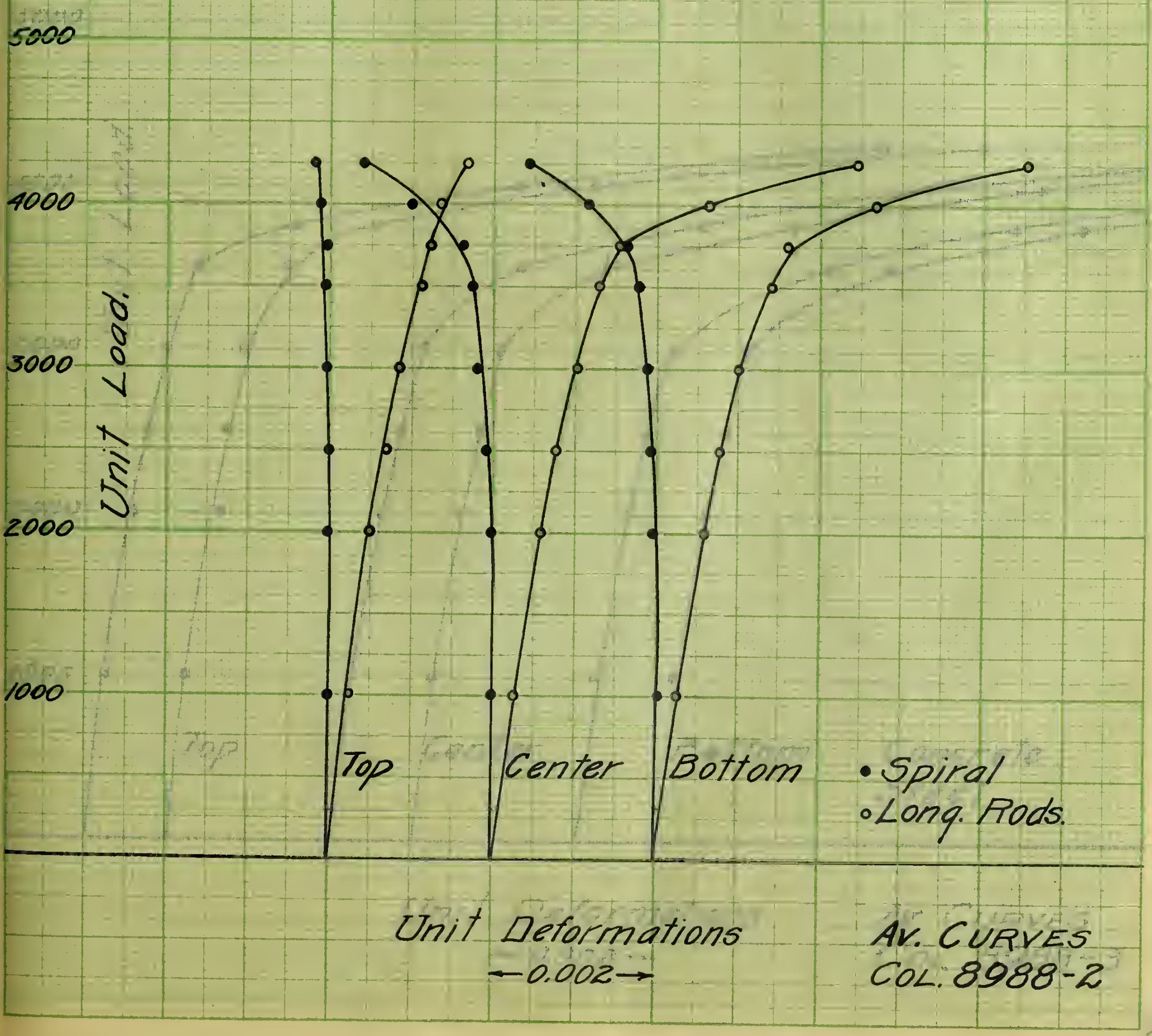


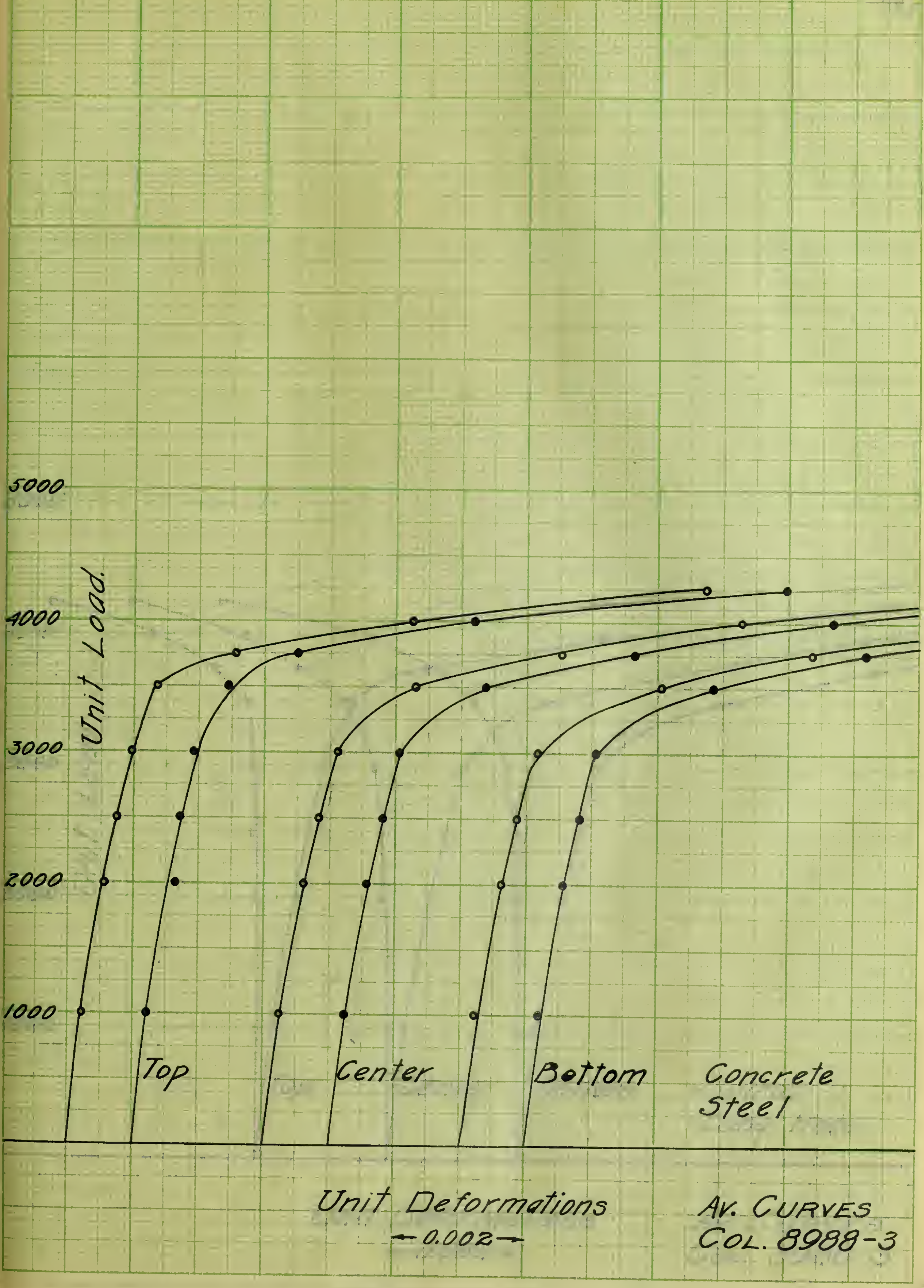
Av. Curves
Col. 8988-1



AV. CURVES
COL. 8988-1


5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Concrete
○ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8988-2


5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Spiral
∘ Long. Rods.
Unit Deformations
←0.002→
Av. Curves
Col. 8988-2


5000
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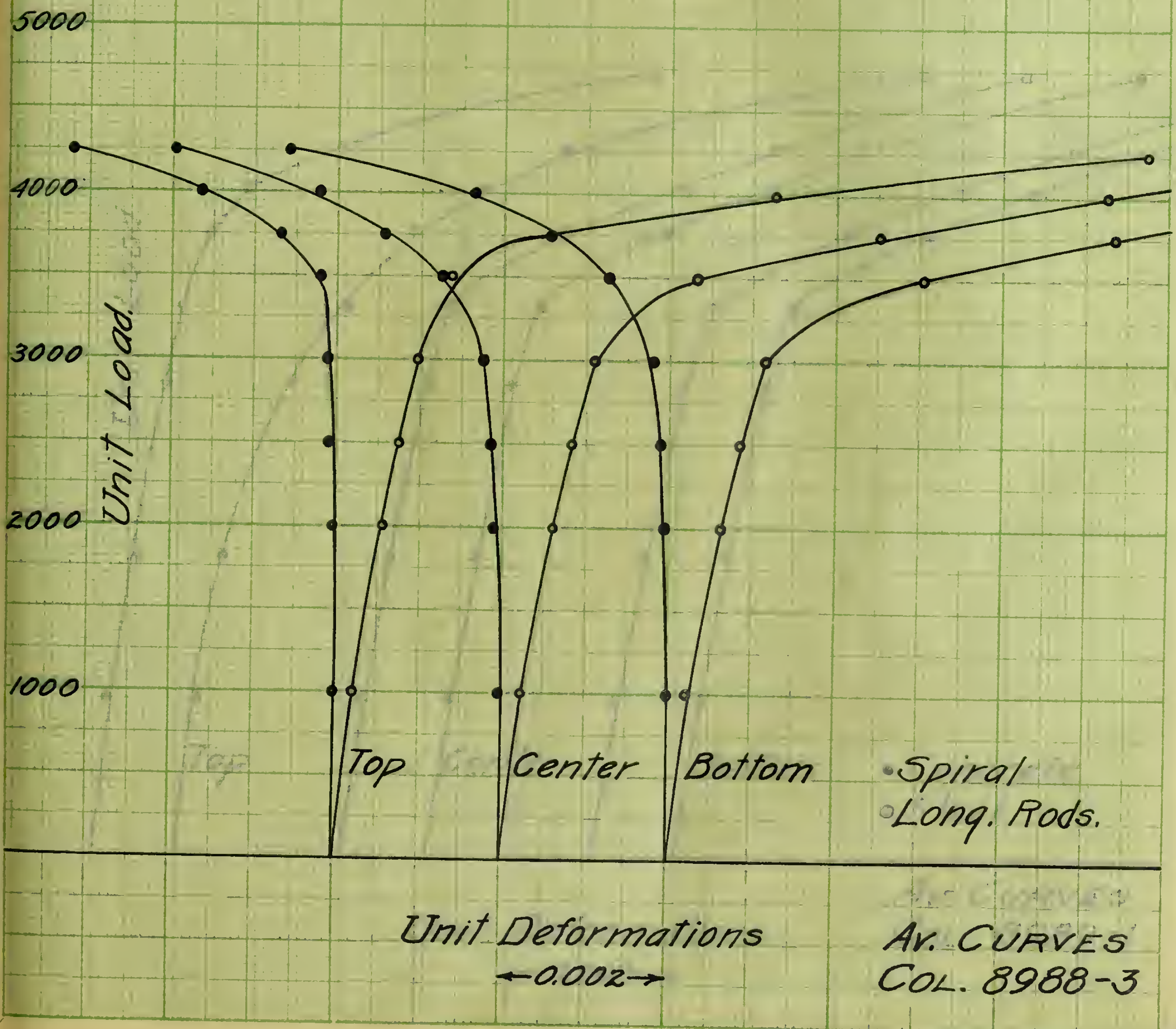
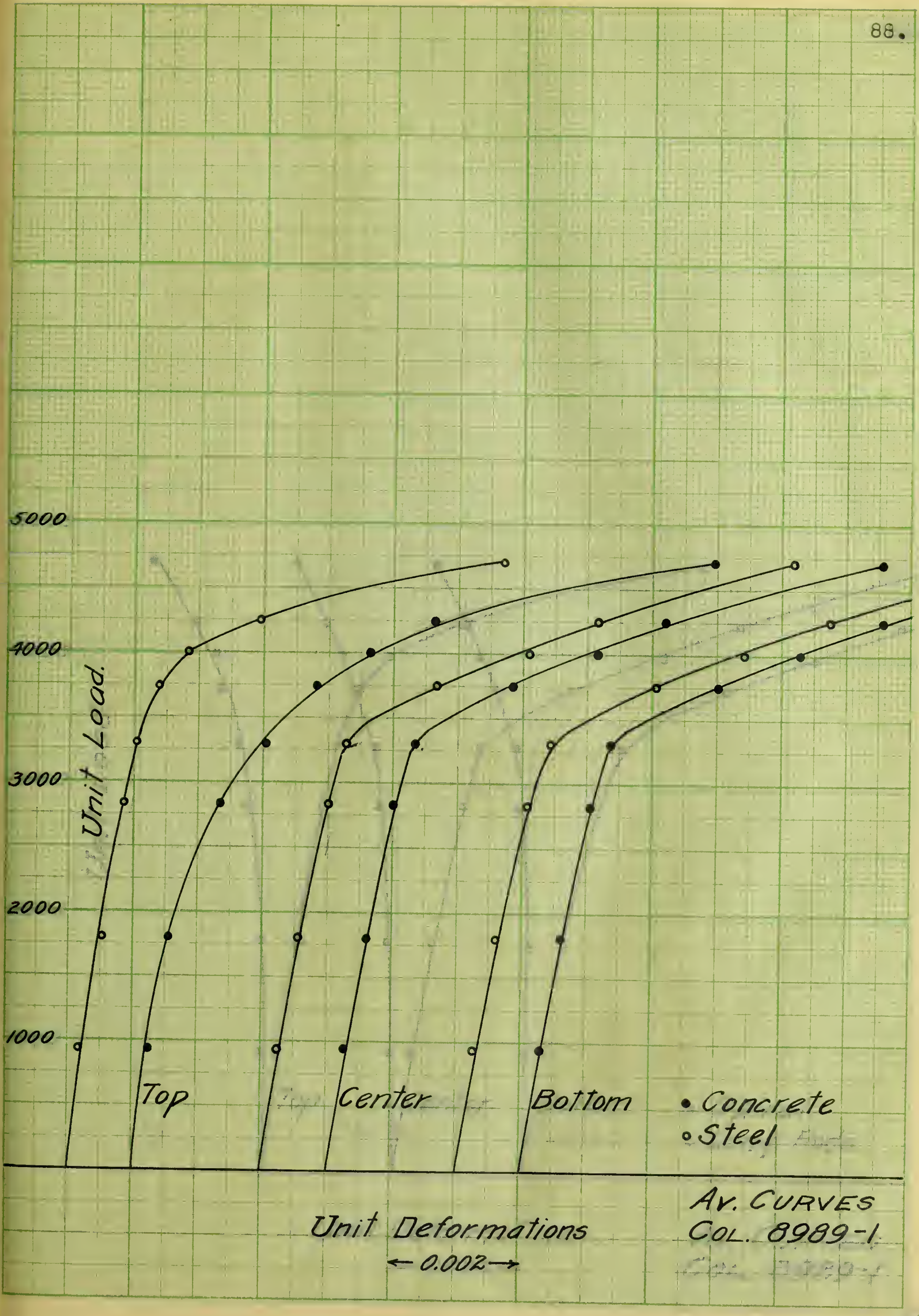
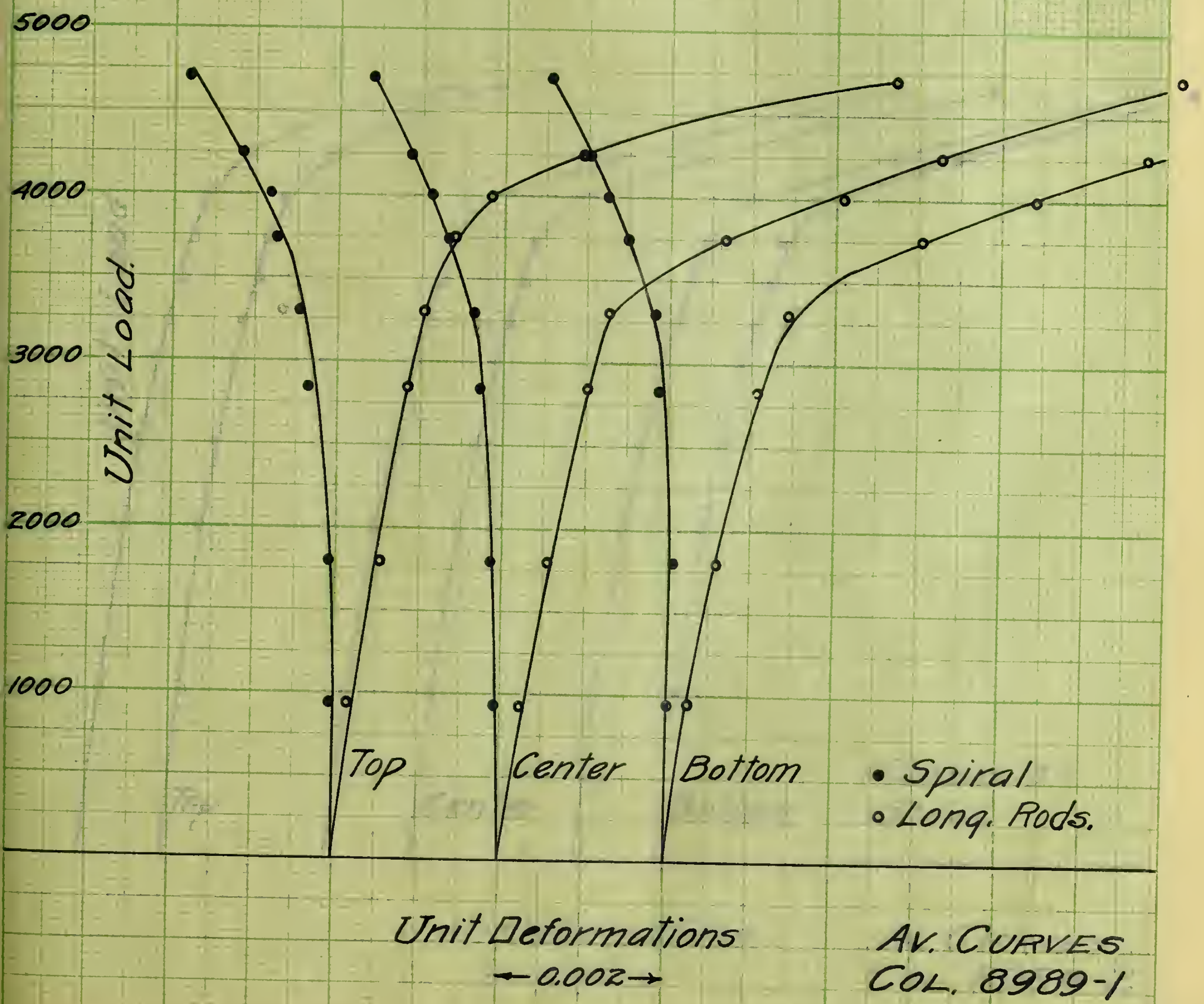
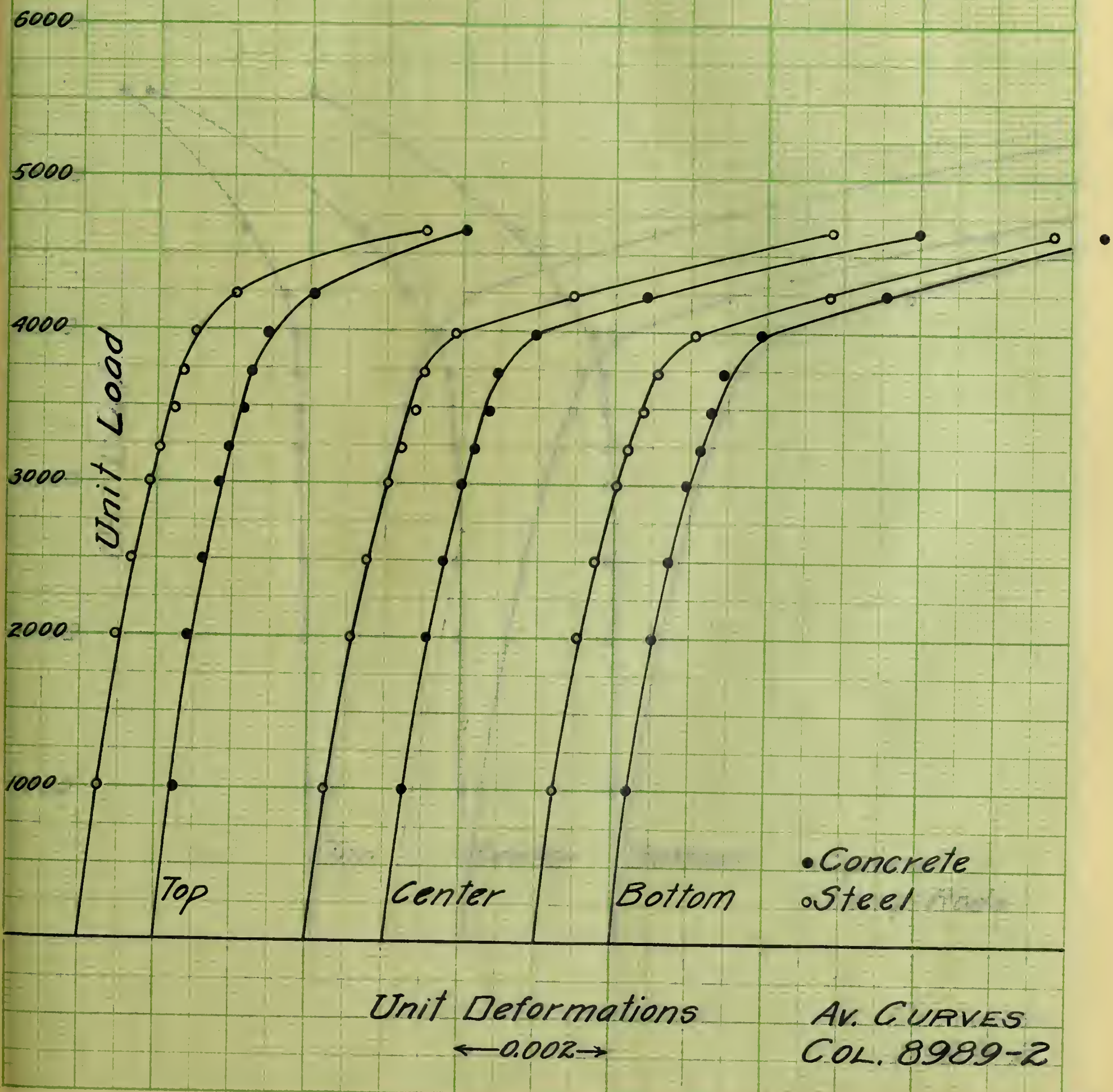
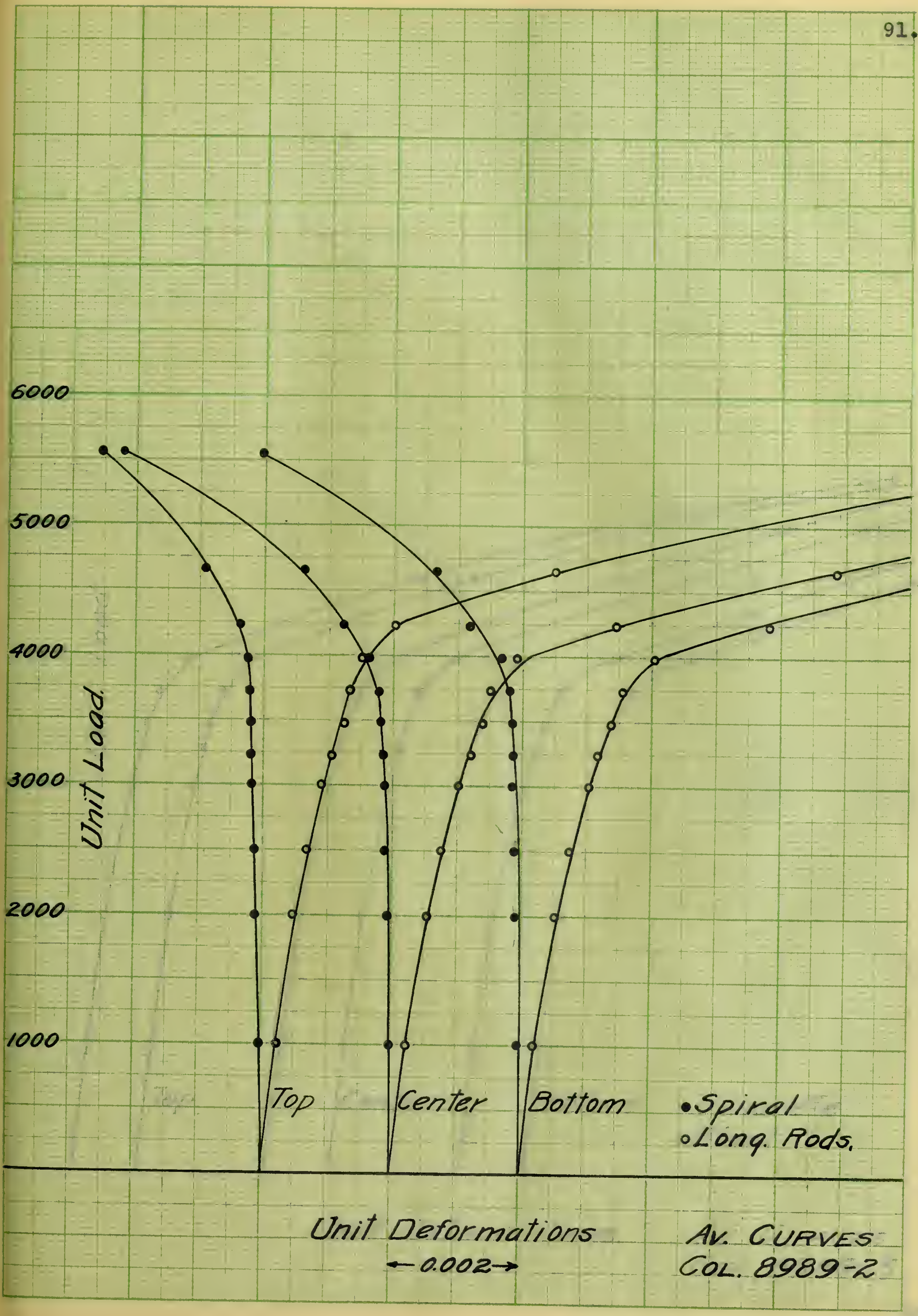
1000
Unit Load.
Top
Center
Bottom
Concrete
Steel
Unit Deformations
← 0.002 →
Av. Curves
Col. 8988-3

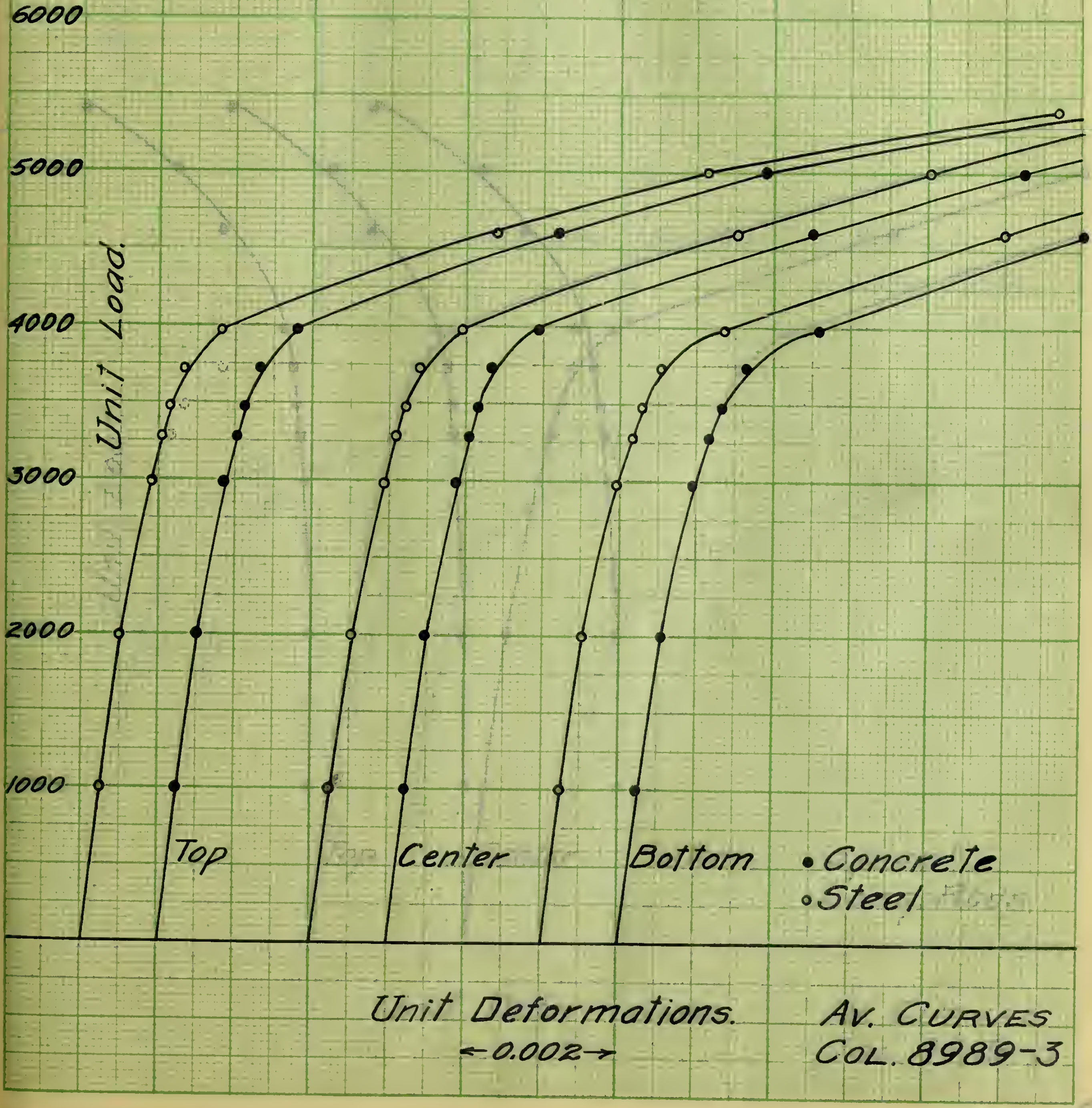

5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
•Spiral
○Long. Rods.
Unit Deformations
←0.002→
Av. Curves
Col. 8988-3

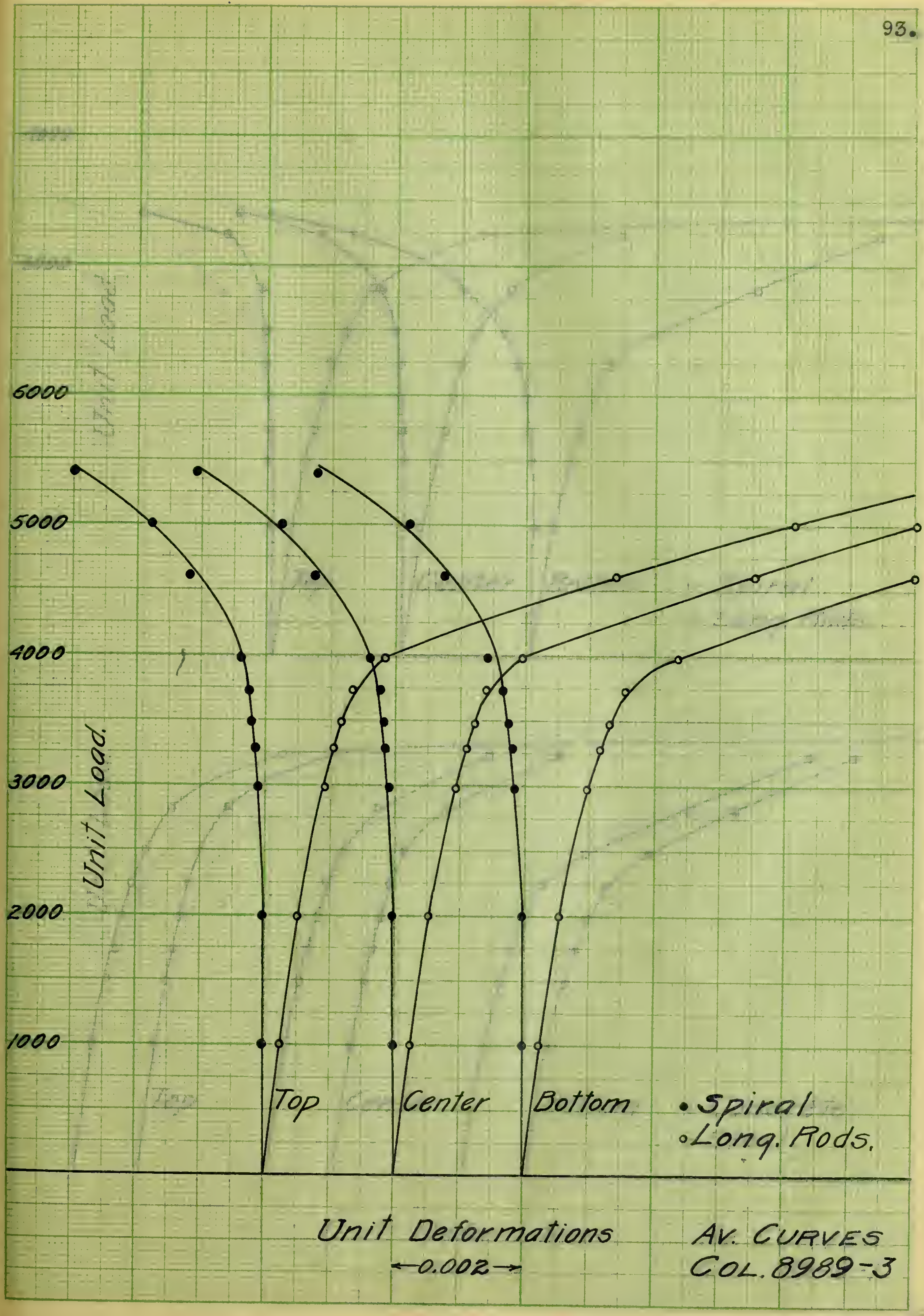

5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Concrete
◦ Steel
Unit Deformations
← 0.002 →
Av. Curves
Col. 8989-1.

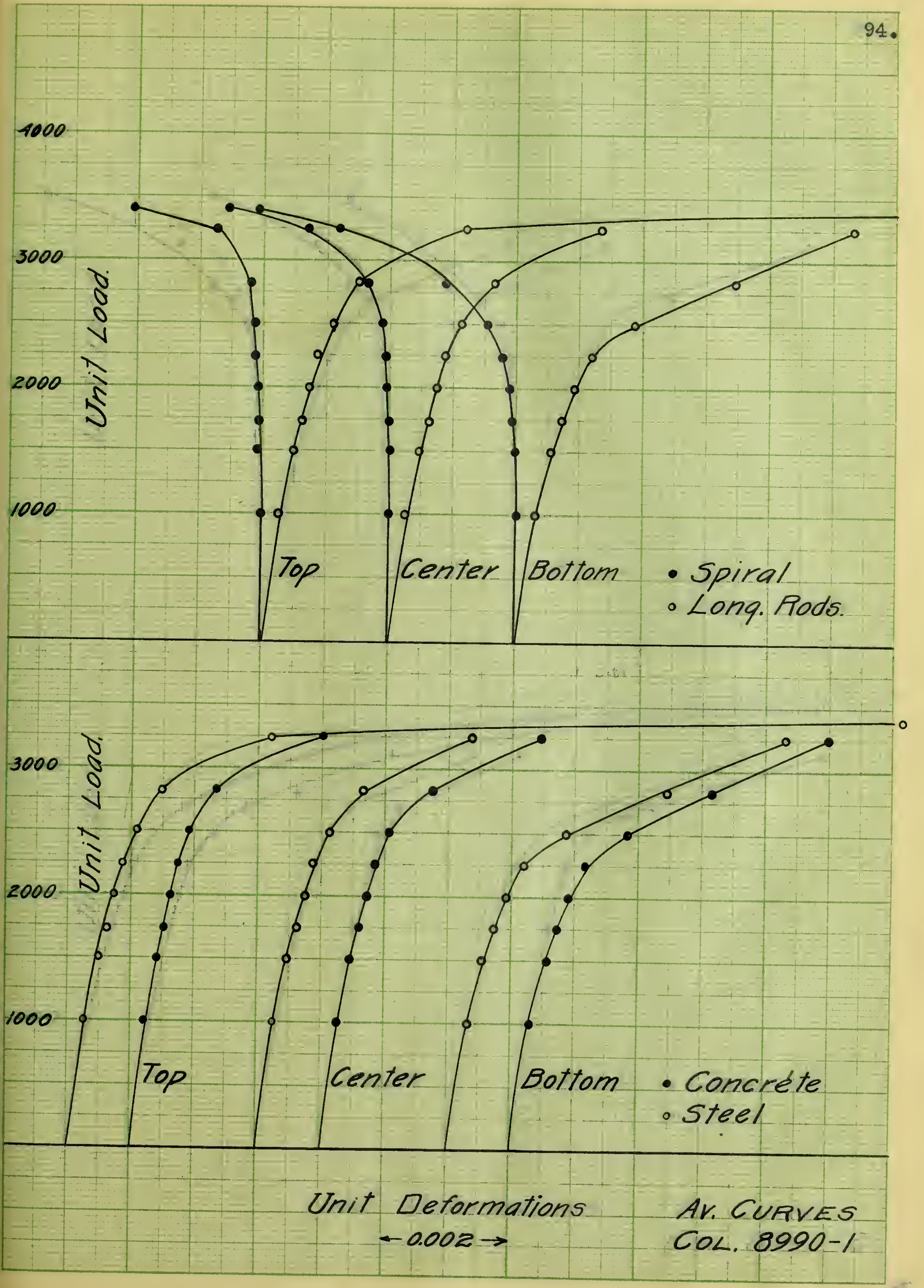

5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Spiral
∘ Long. Rods.
Unit Deformations
←0.002→
Av. Curves
Col. 8989-1


6000
5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
●Concrete
○Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8989-2

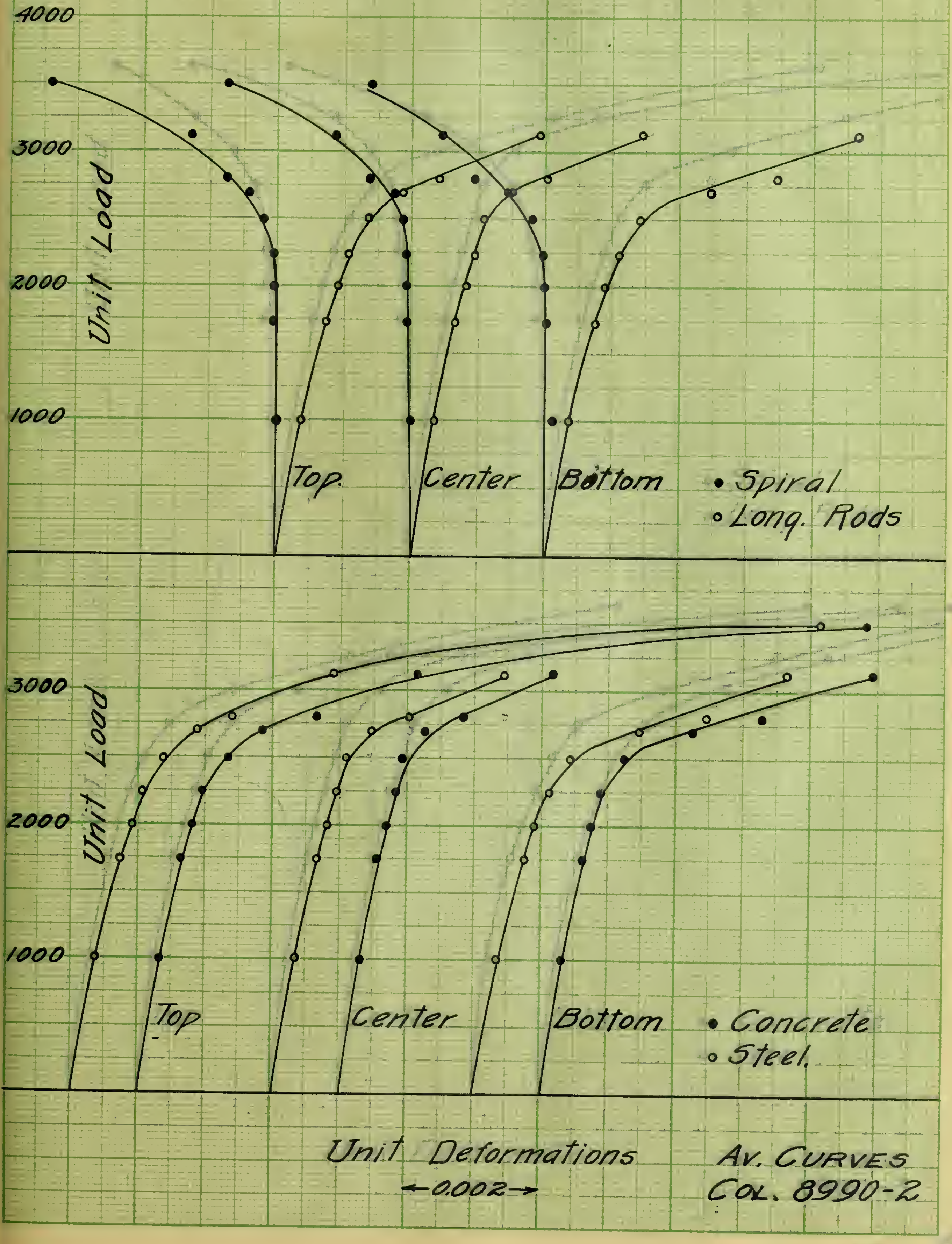

6000
5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
•Spiral
∘Long. Rods.
Unit Deformations
←0.002→
Av. Curves
Col. 8989-2

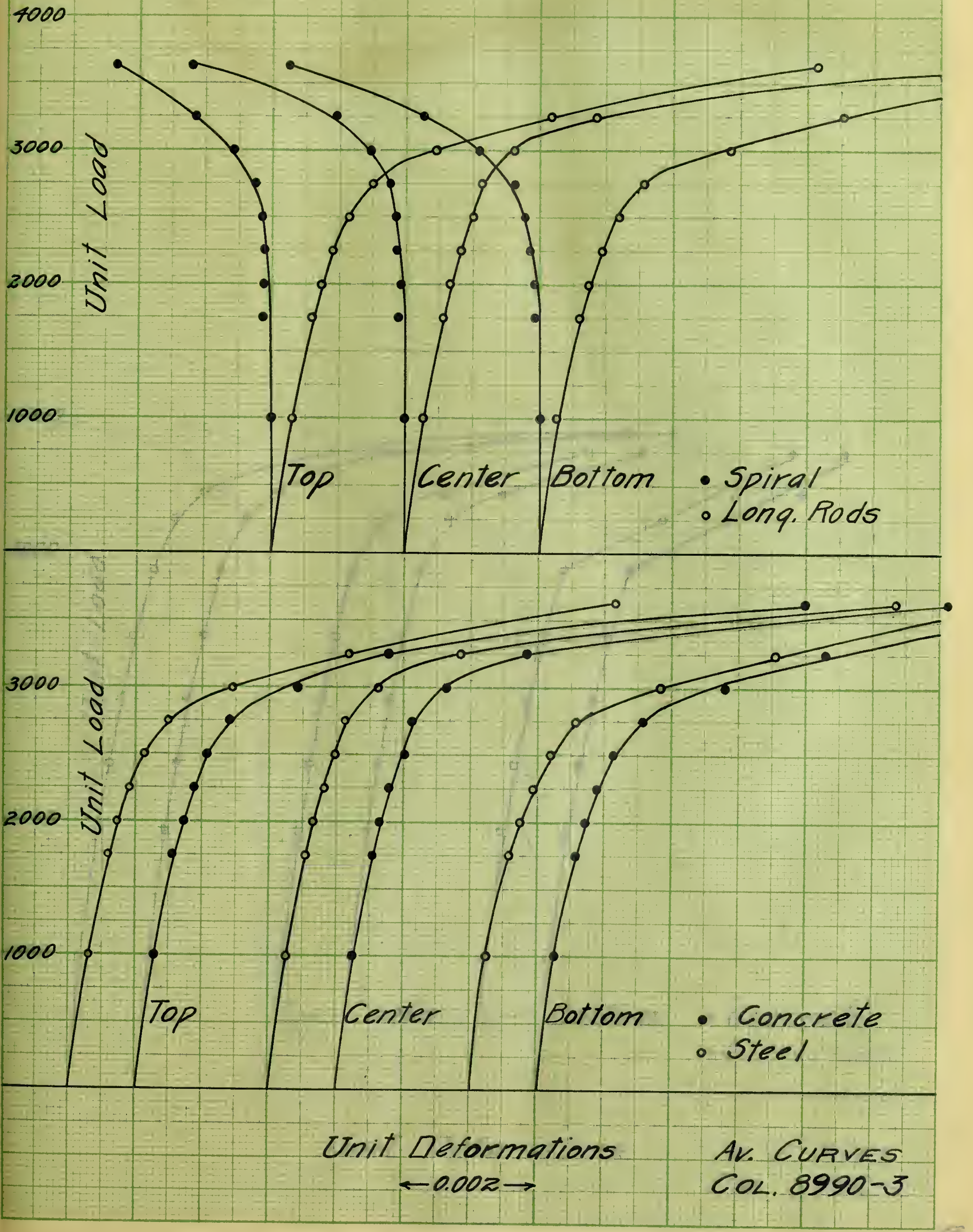

6000
5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Concrete
∘ Steel
Unit Deformations.
←0.002→
Av. Curves
Col. 8989-3

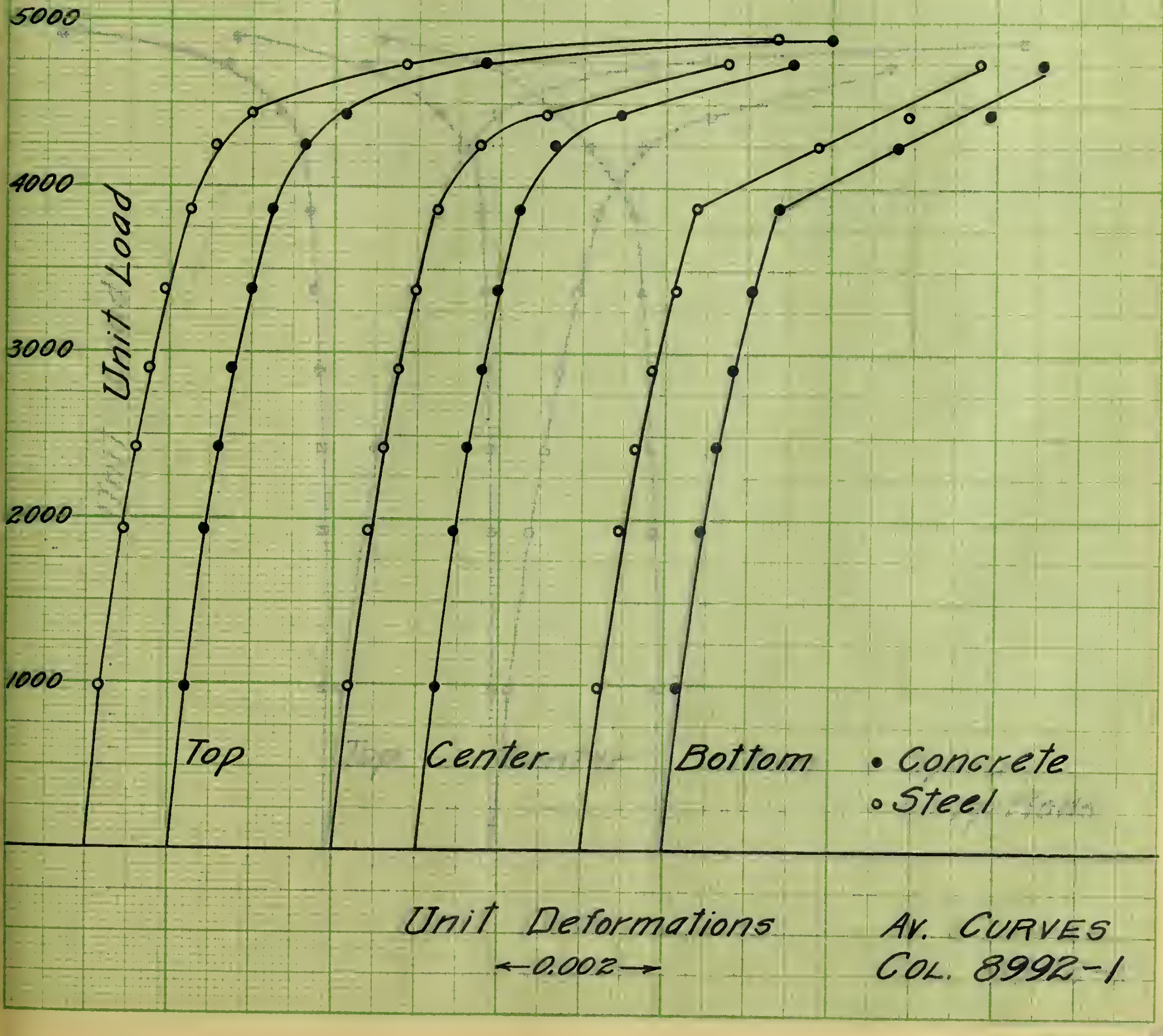

6000
5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Spiral
◦ Long. Rods.
Unit Deformations
←0.002→
Av. Curves
Col. 8989-3

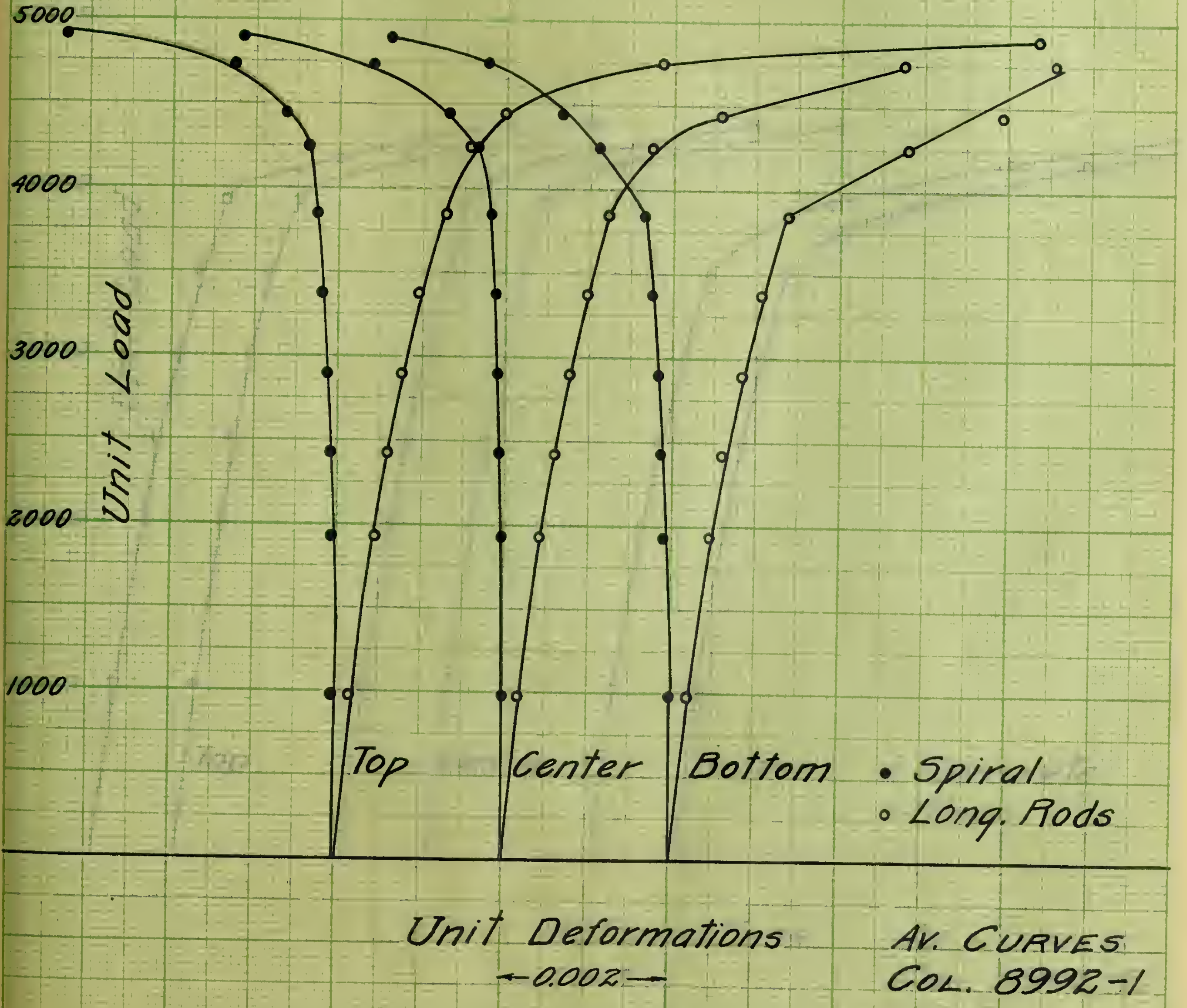


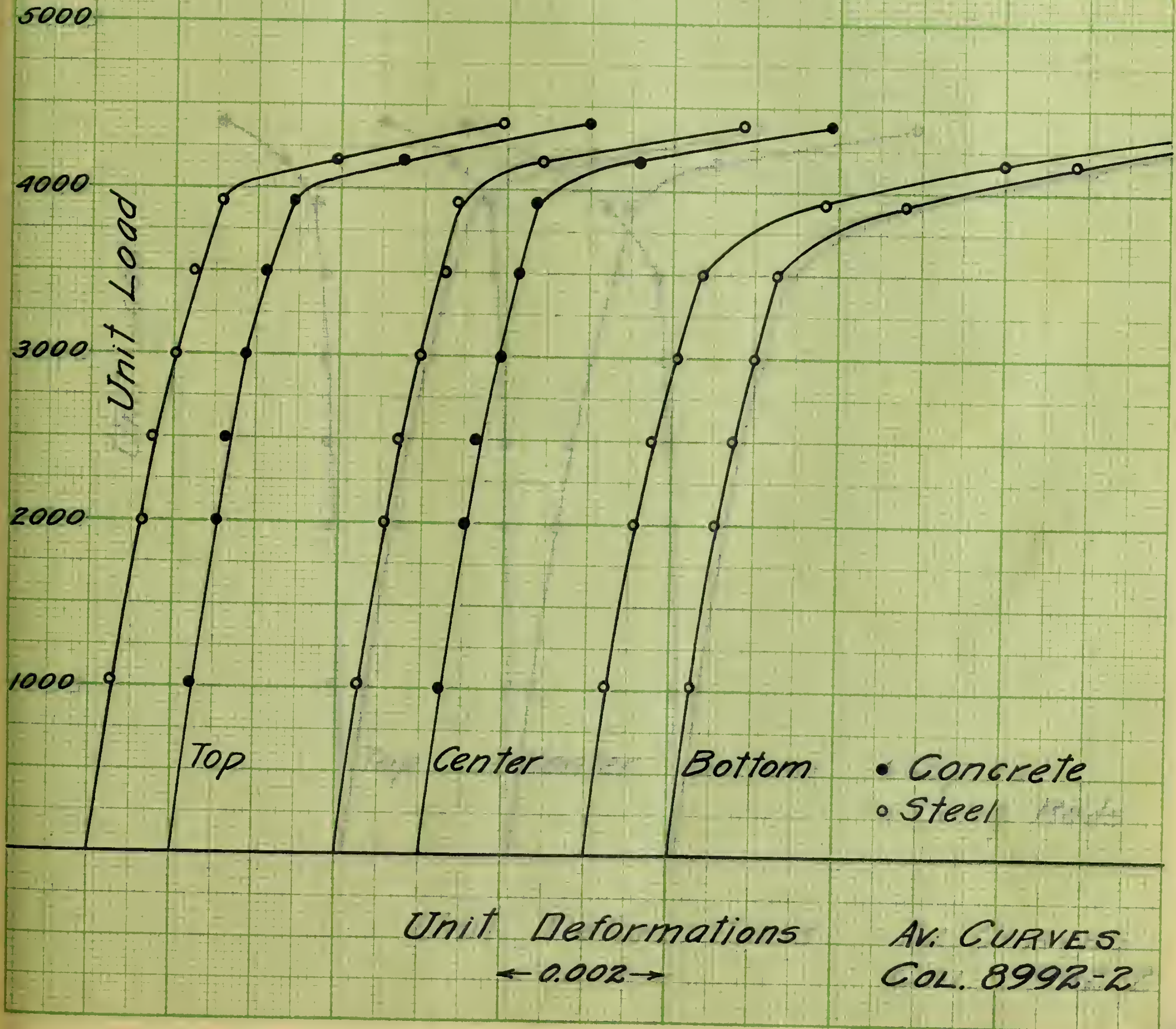
Av. CURVES
COL. 8990-1


4000
3000
2000
1000
Unit Load
Top
Center
Bottom
● Spiral
○ Long. Rods
3000
2000
1000
Unit Load
Top
Center
Bottom
● Concrete
○ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8990-2


4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Spiral
∘ Long. Rods
3000
2000
1000
Unit Load
Top
Center
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8990-3


5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8992-1


5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Spiral
∘ Long. Rods
Unit Deformations
←0.002→
Av. Curves
Col. 8992-1


5000
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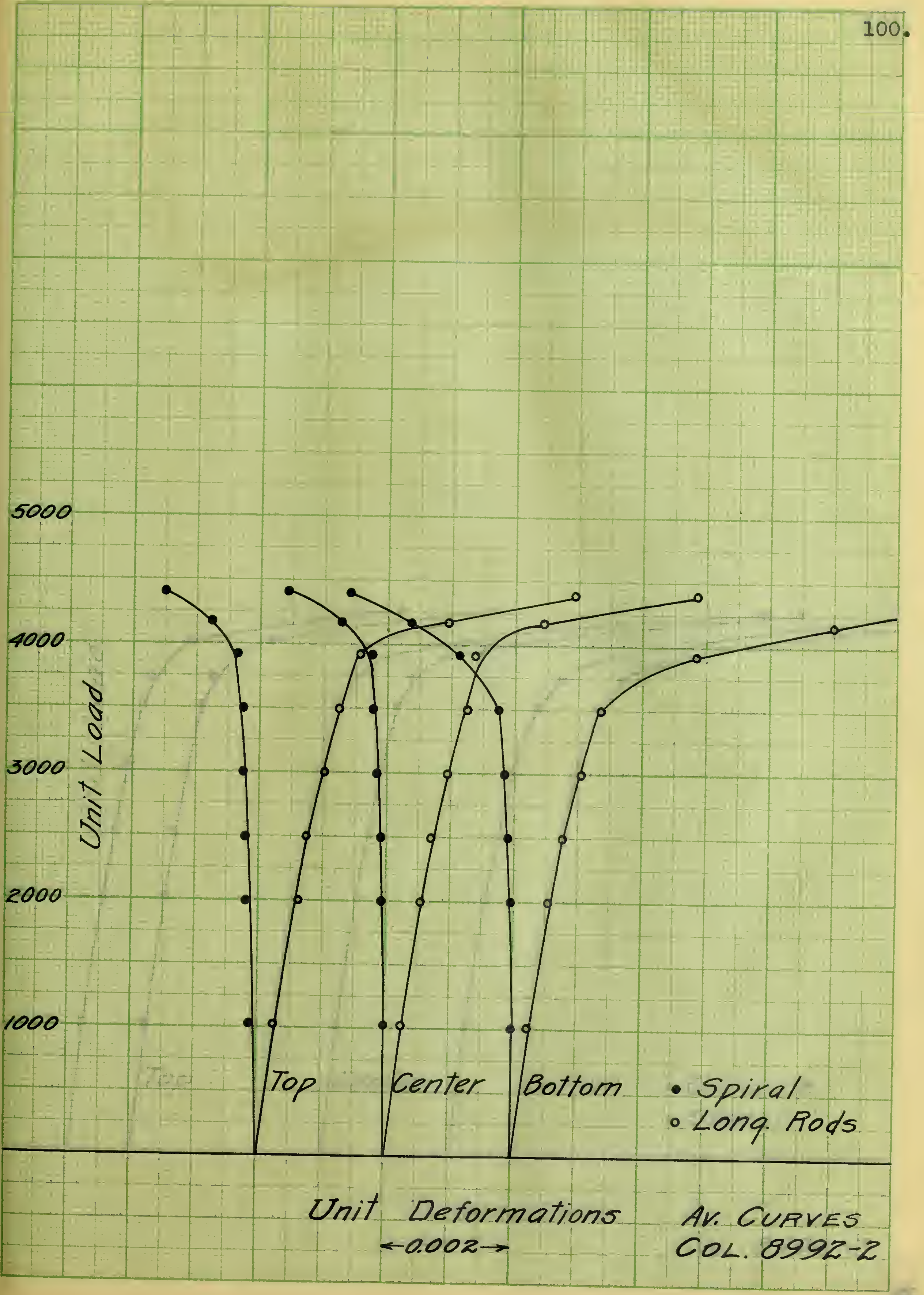
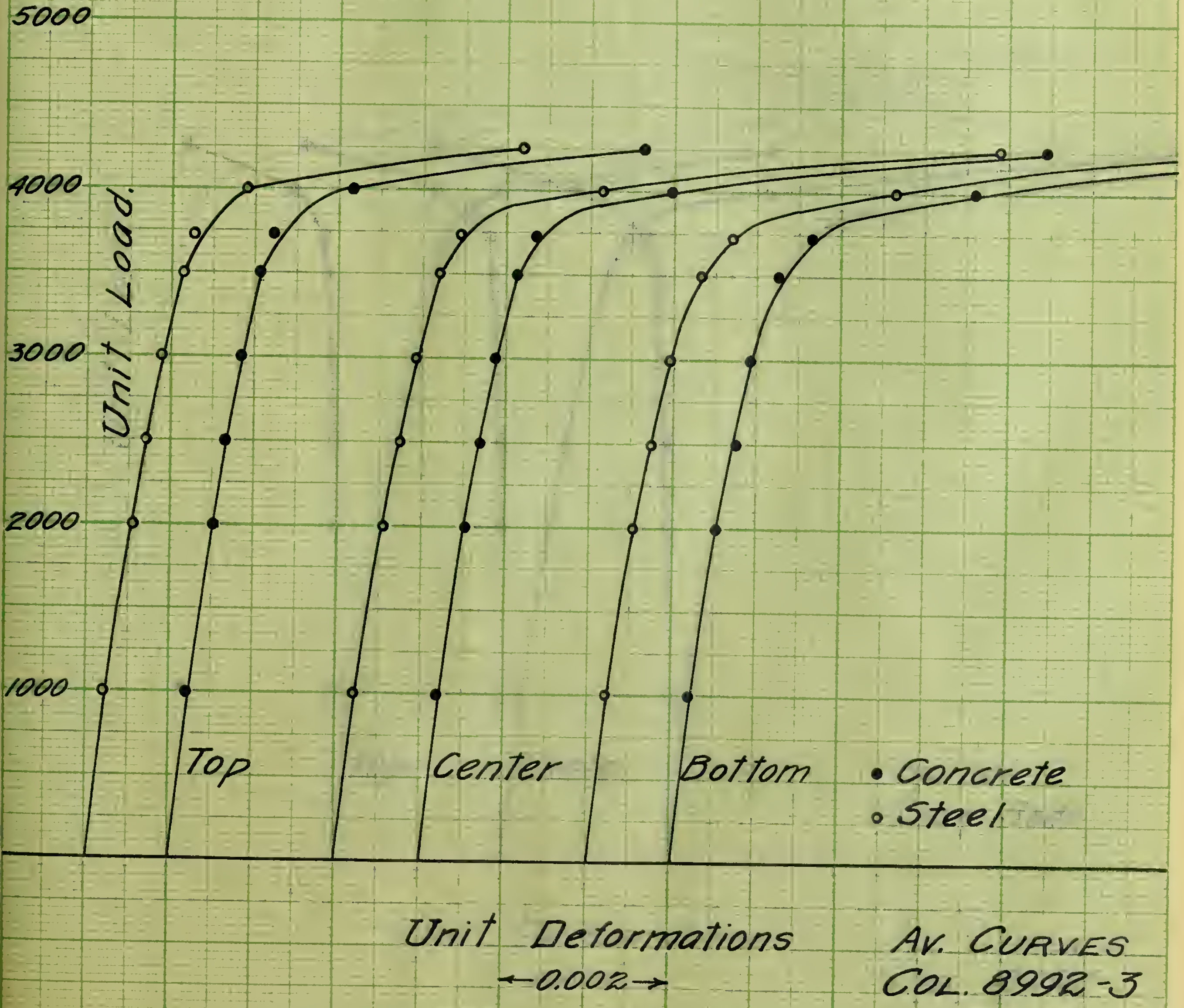
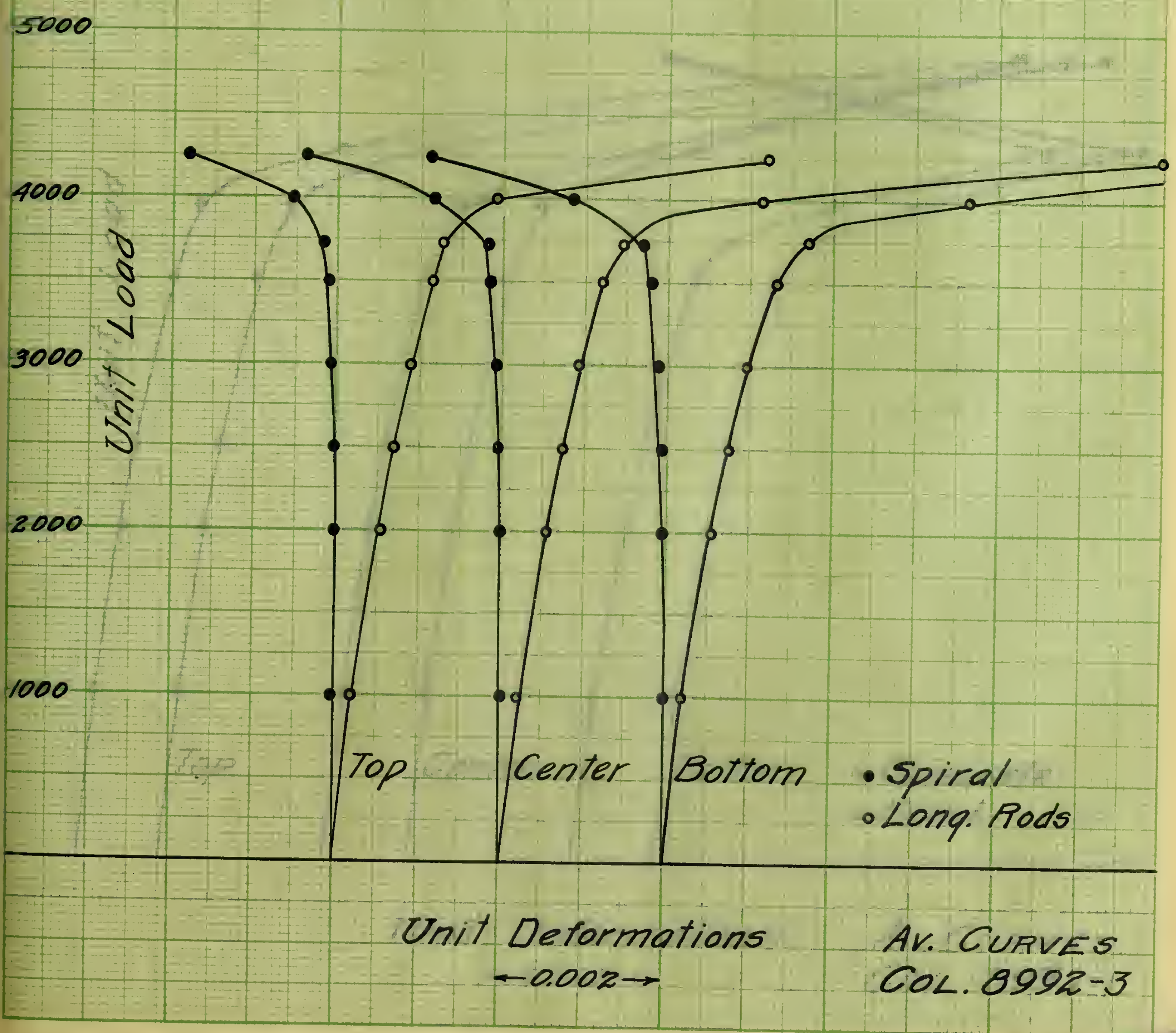
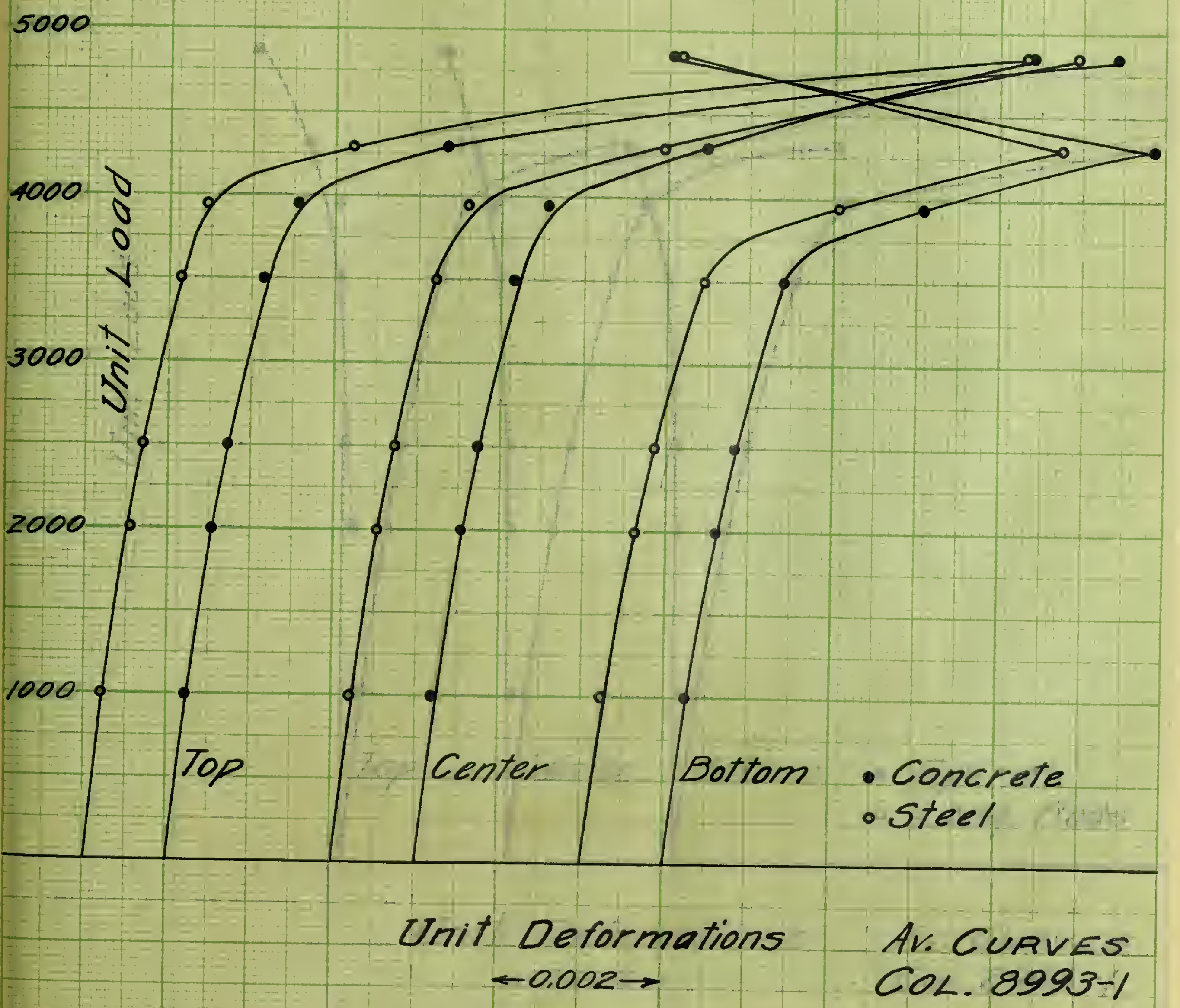
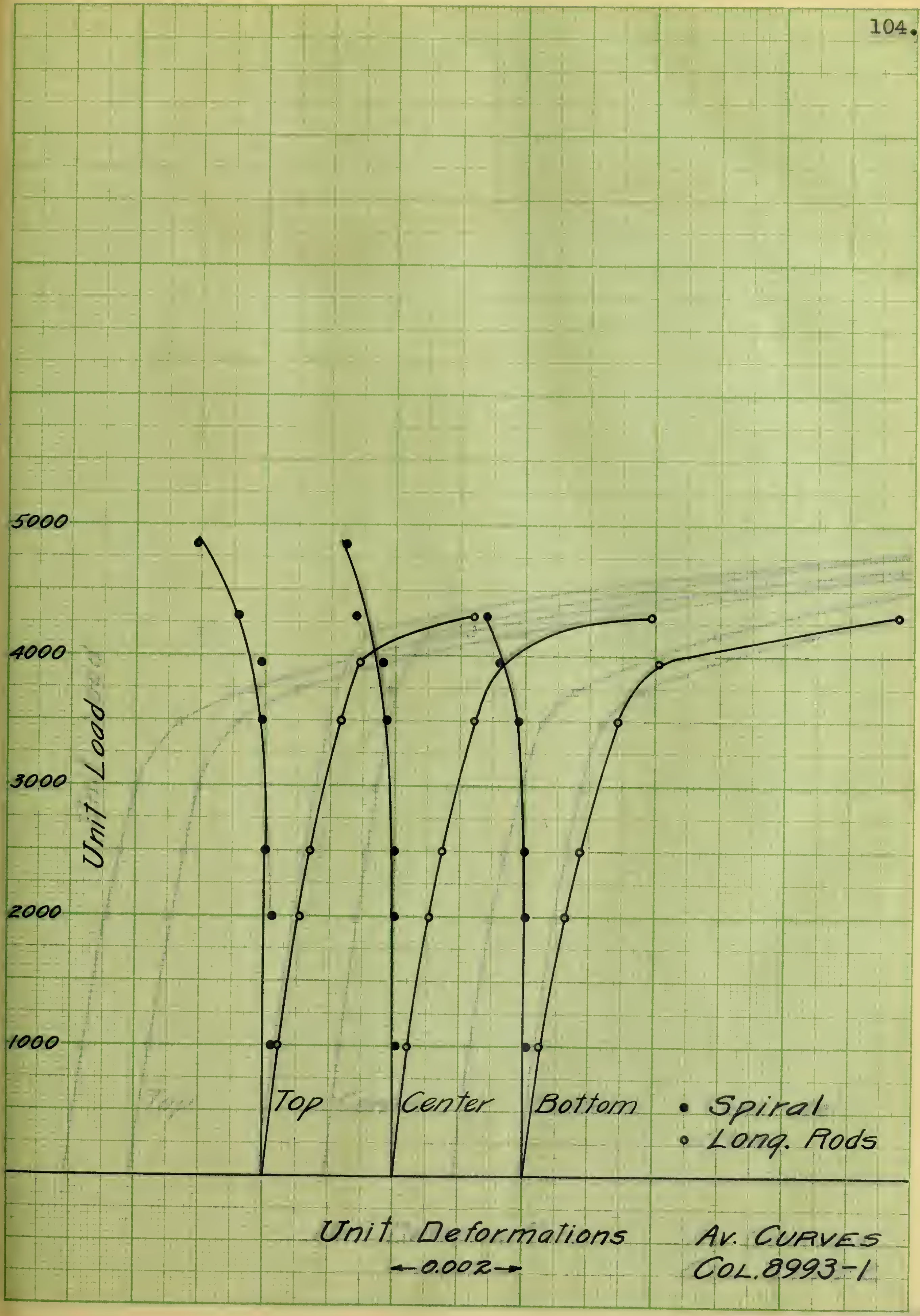
3000
2000
1000
Unit Load
Top
Center
Bottom
• Concrete
○ Steel
Unit Deformations
← 0.002 →
Av. Curves
Col. 8992-2

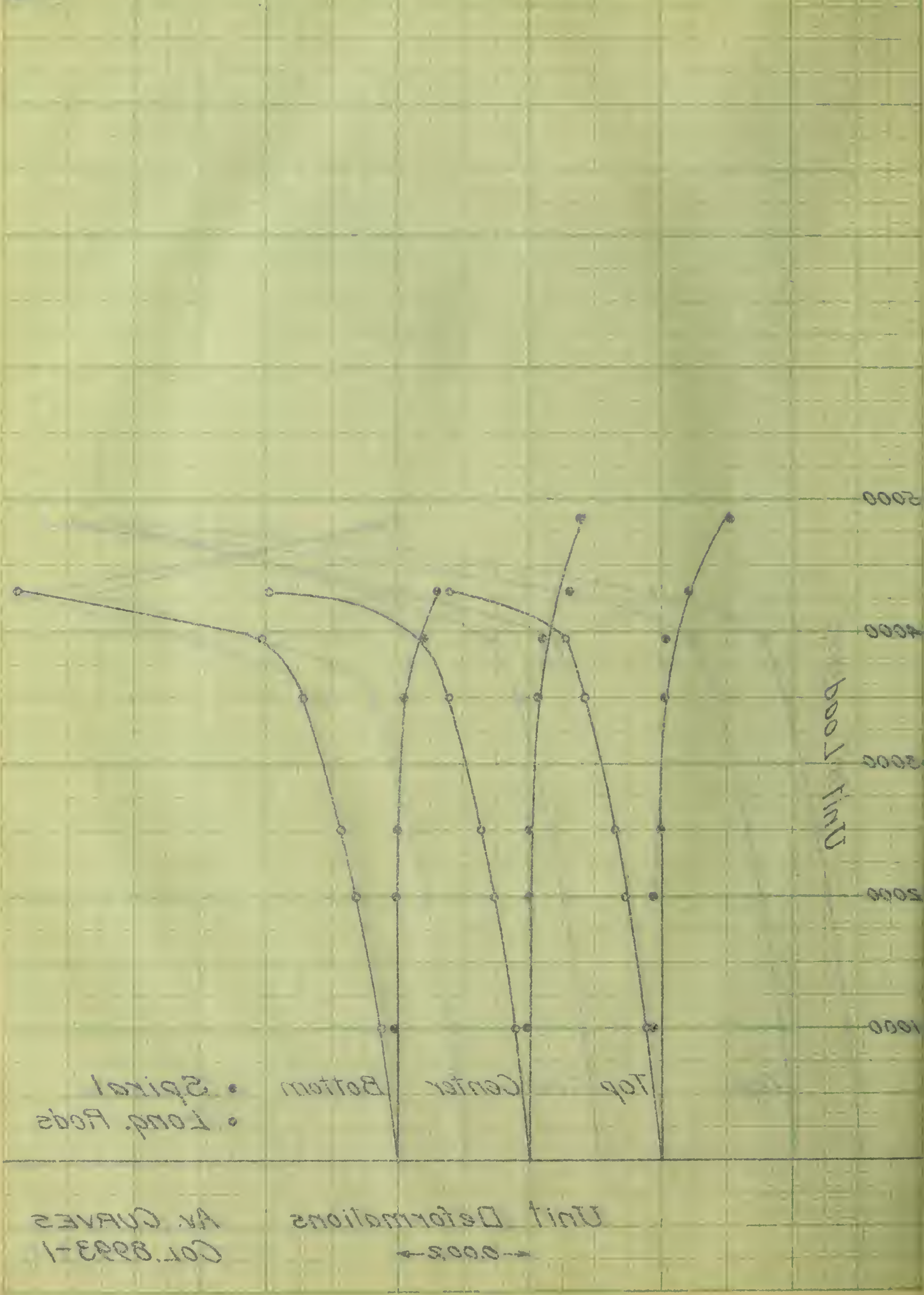

5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
● Spiral
○ Long. Rods
Unit Deformations
←0.002→
Av. Curves
Col. 8992-2

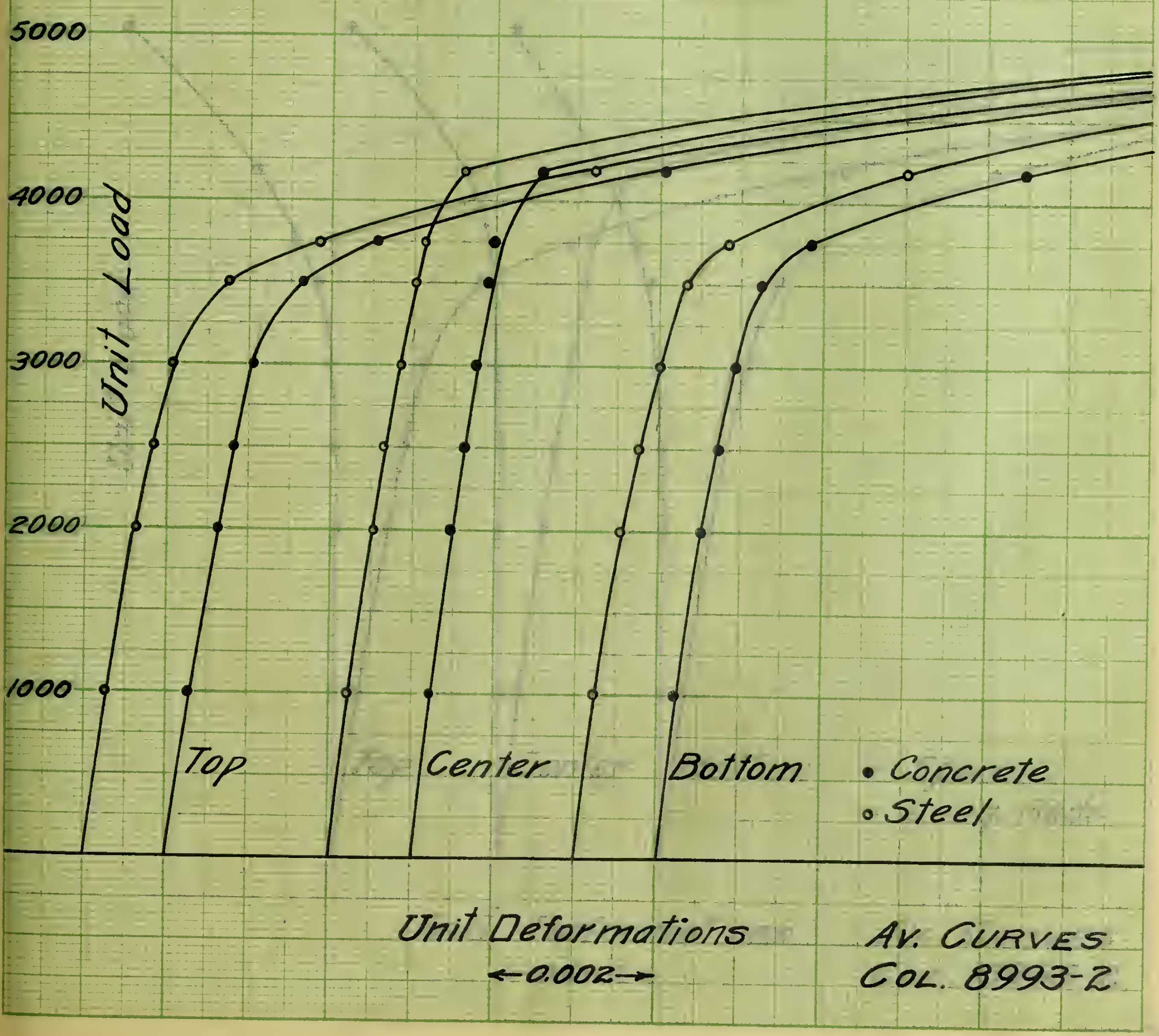

5000
4000
3000
2000
1000
Unit Load.
Top
Center
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8992-3

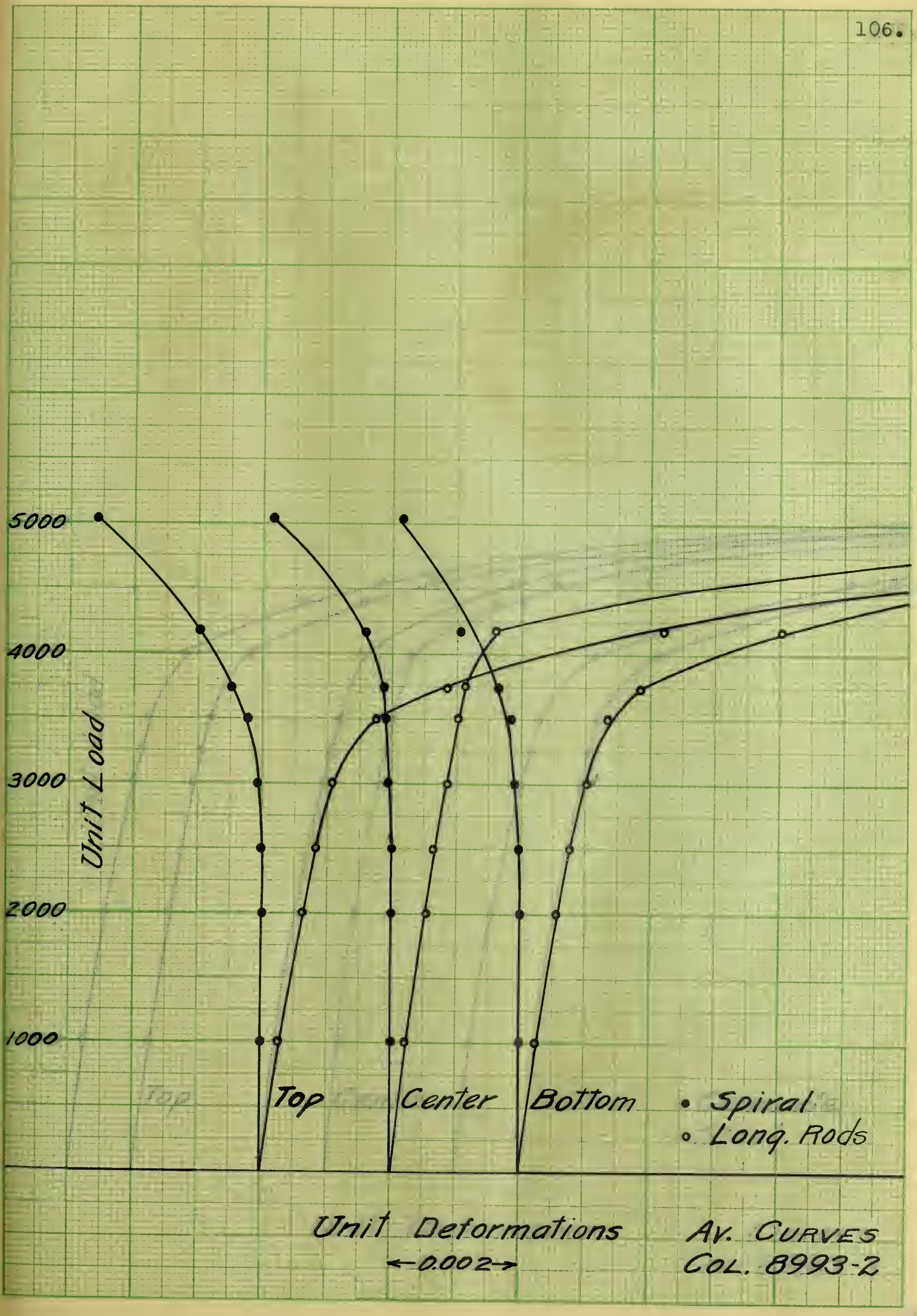

5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Spiral
○ Long. Rods
Unit Deformations
←0.002→
Av. Curves
Col. 8992-3

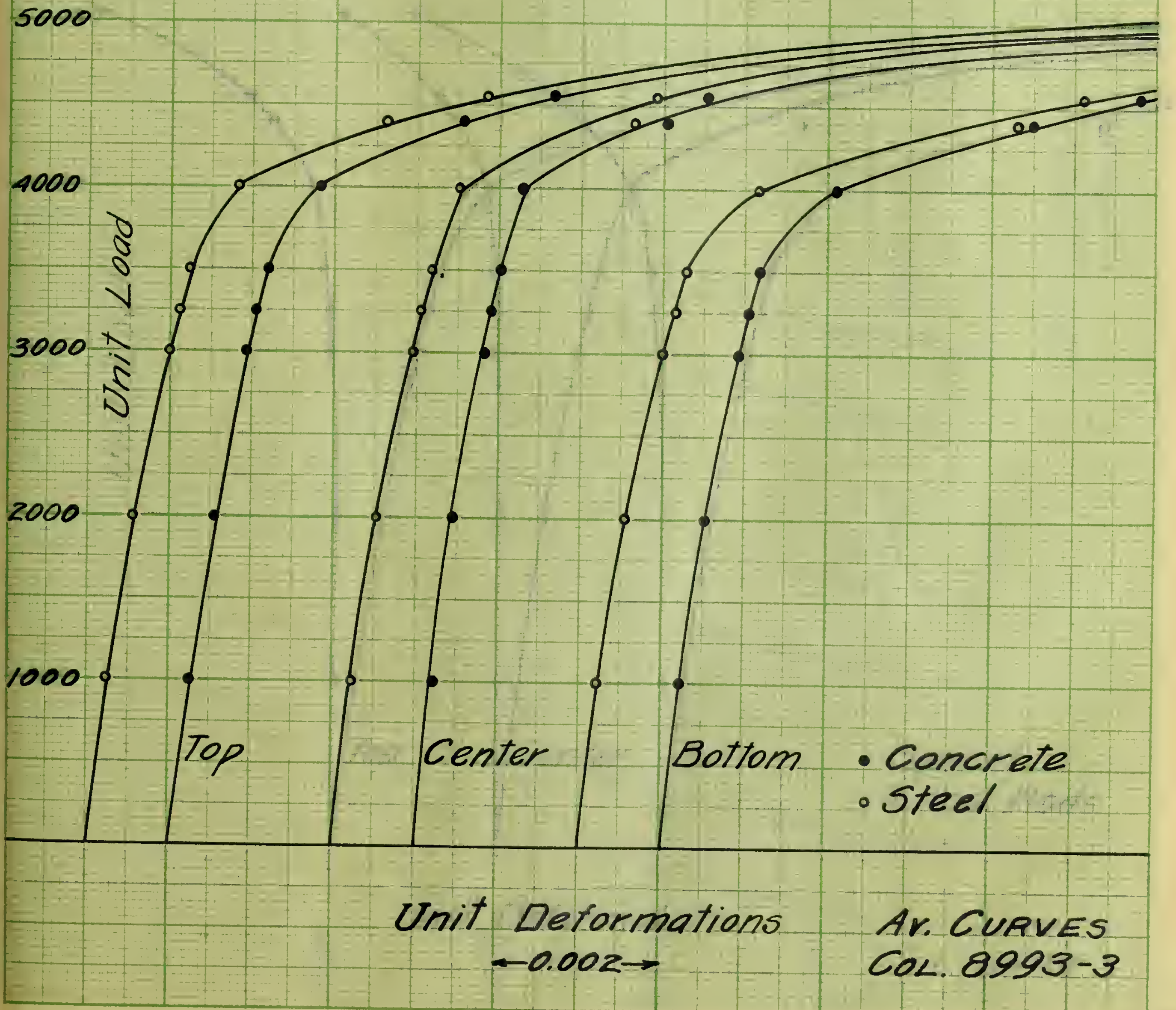

5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
● Concrete
○ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8993-1

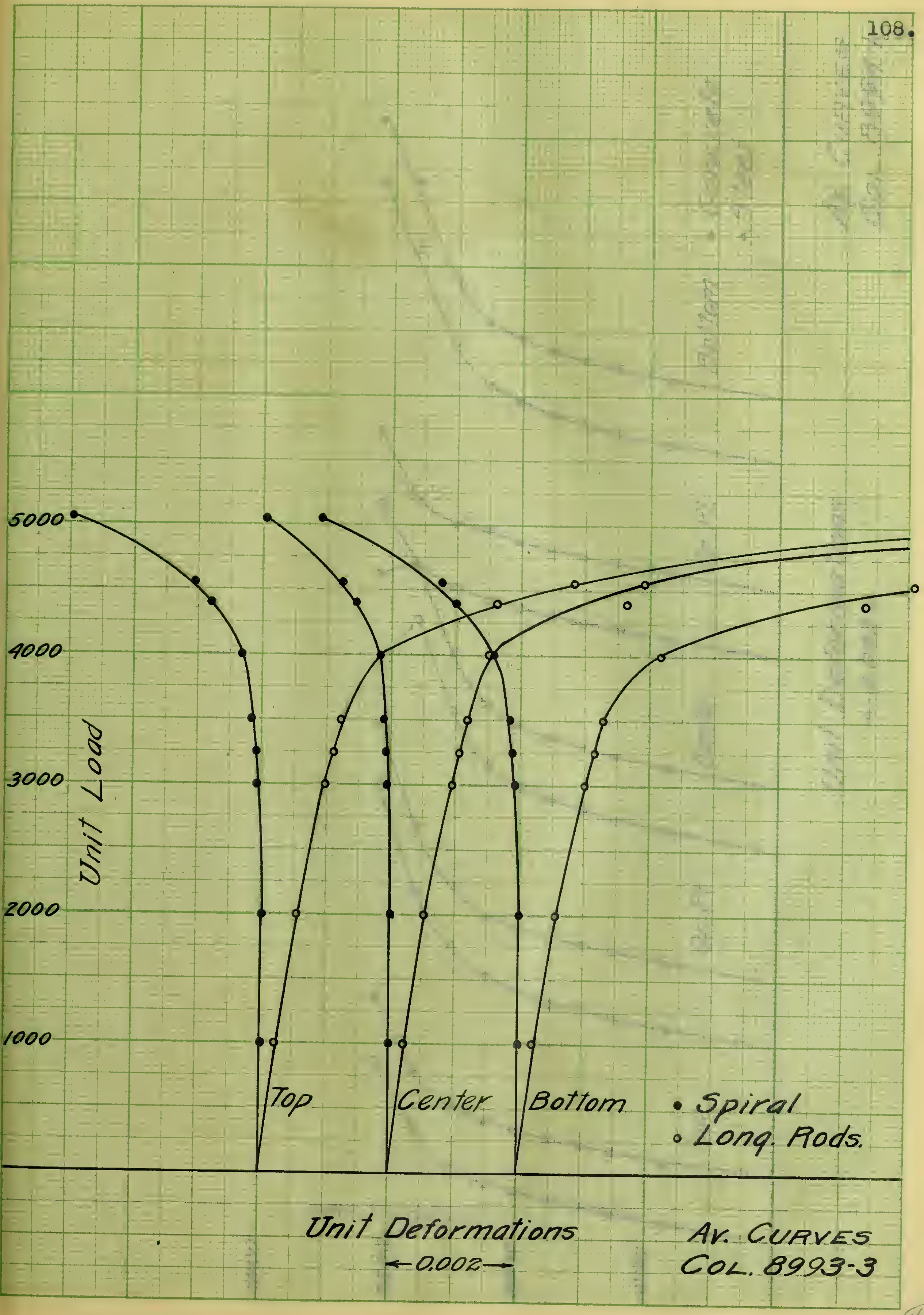

5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
● Spiral
○ Long. Rods
Unit Deformations
←0.002→
Av. Curves
Col. 8993-1

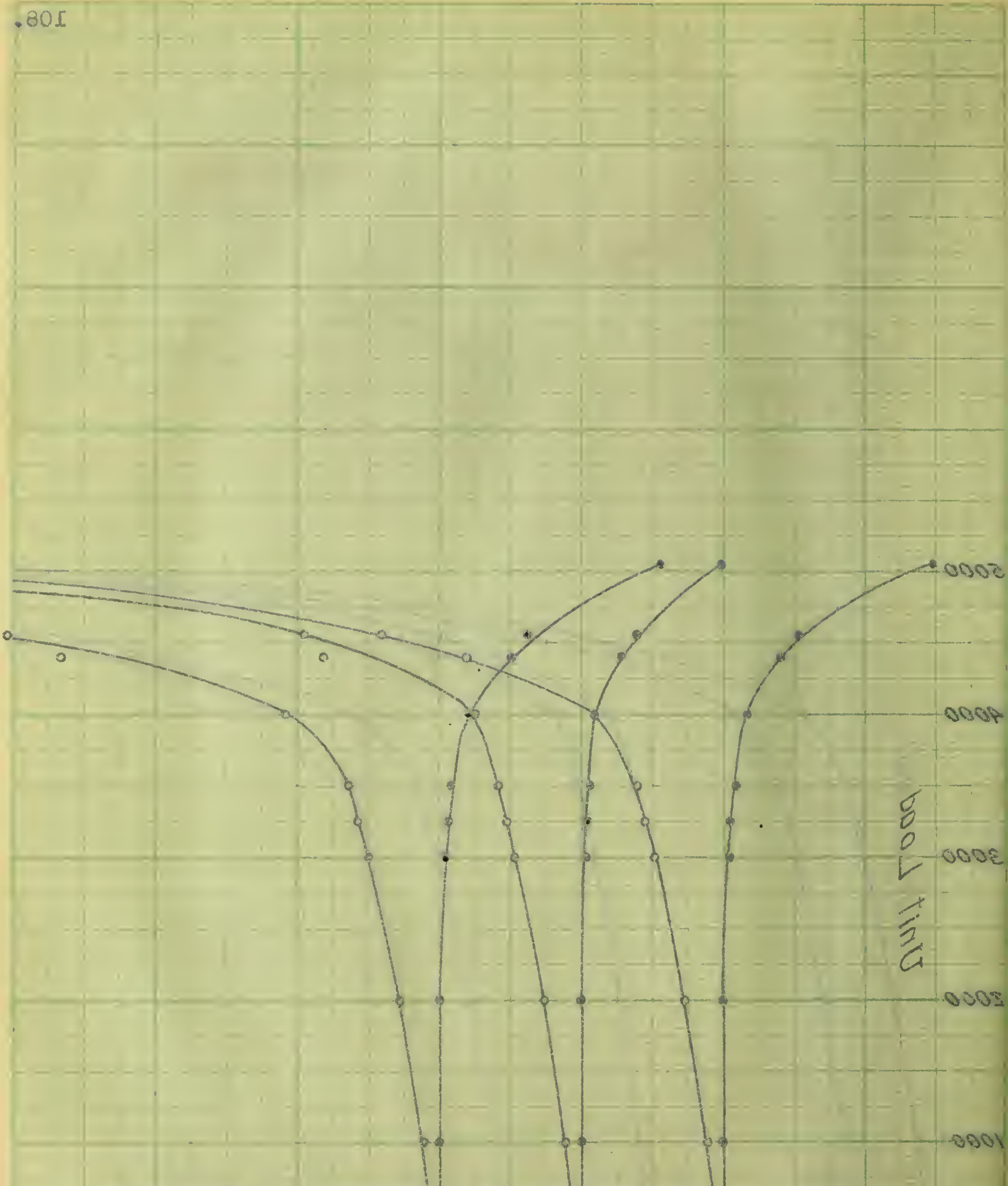

5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Spiral
∘ Long. Rods
Unit Deformations
←0.0002→
Ax. CURVES
Col. 8993-1

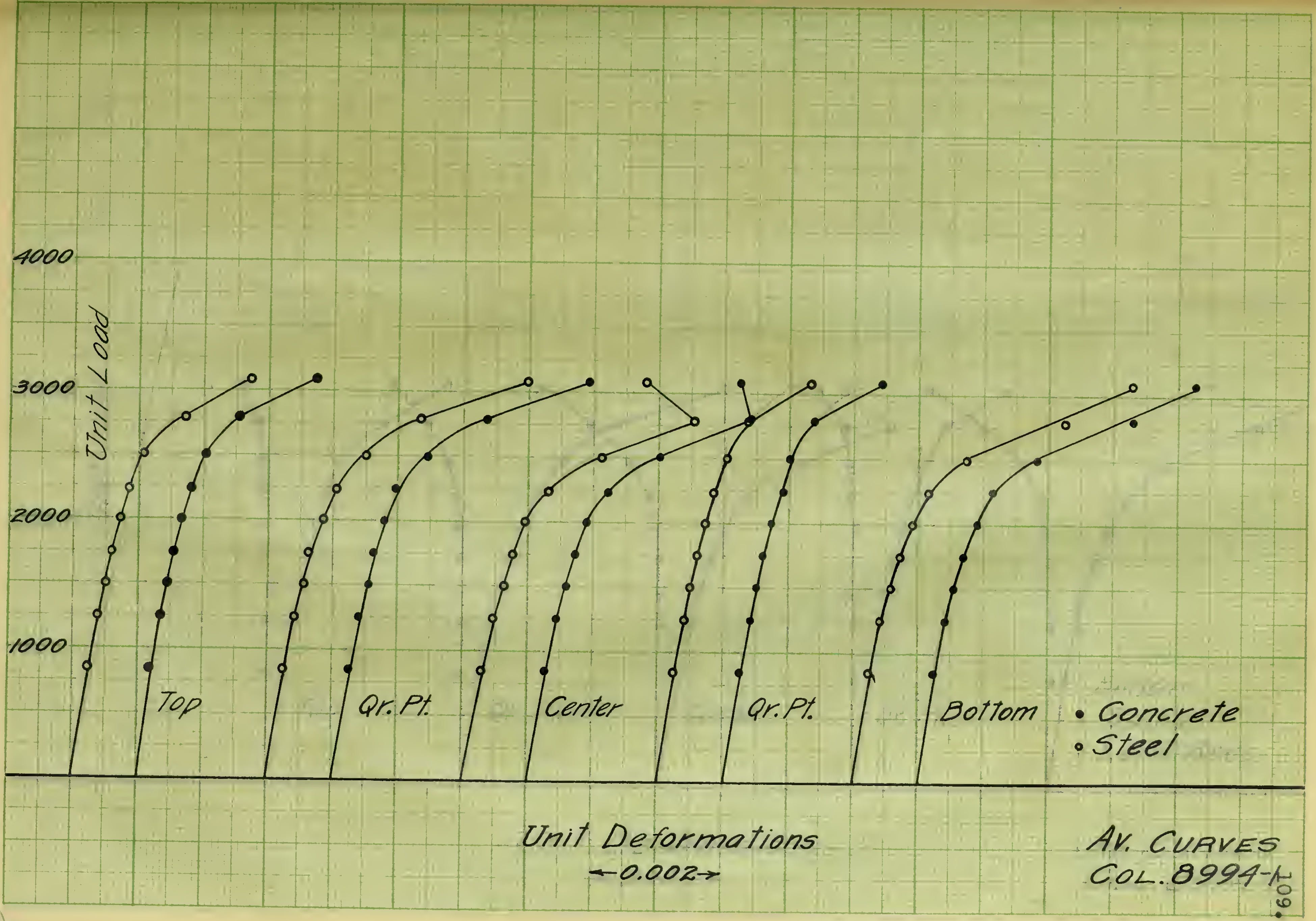

5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Concrete
◦ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8993-2


5000
4000
3000
2000
1000
Unit Load
Top
Top
Center
Bottom
• Spiral
∘ Long. Rods
Unit Deformations
←0.002→
Av. Curves
Col. 8993-2

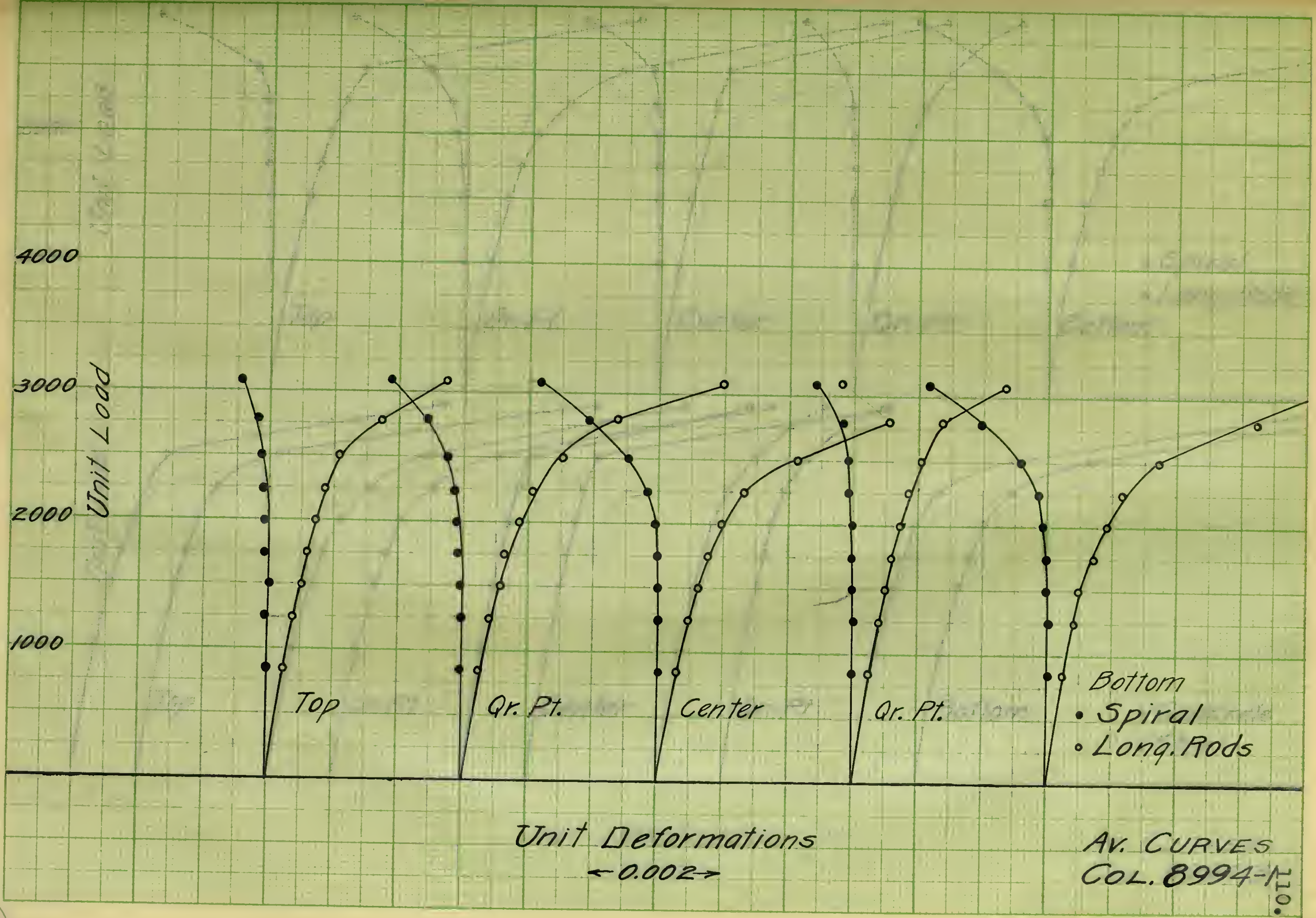

5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Concrete
◦ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8993-3


5000
4000
3000
2000
1000
Unit Load
Top
Center
Bottom
• Spiral
∘ Long. Rods.
Unit Deformations
←0.002→
Av. Curves
Col. 8993-3

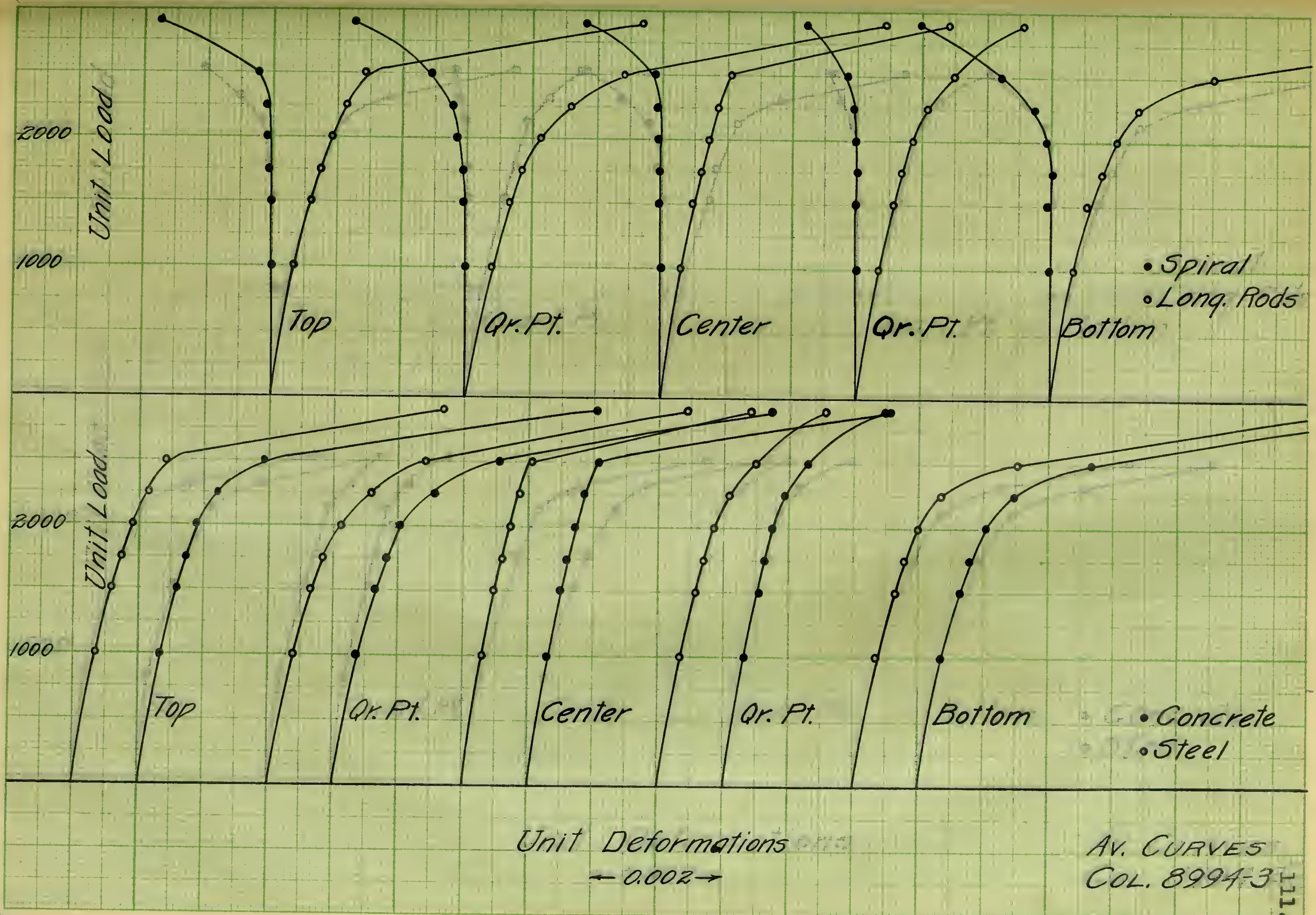

Unit Load
1000
2000
3000
4000
5000
Top
Center
Bottom
• Spiral
○ Long Rods.
Unit Deformations
←.0002→
Ax. Curves
Col. 8993-3

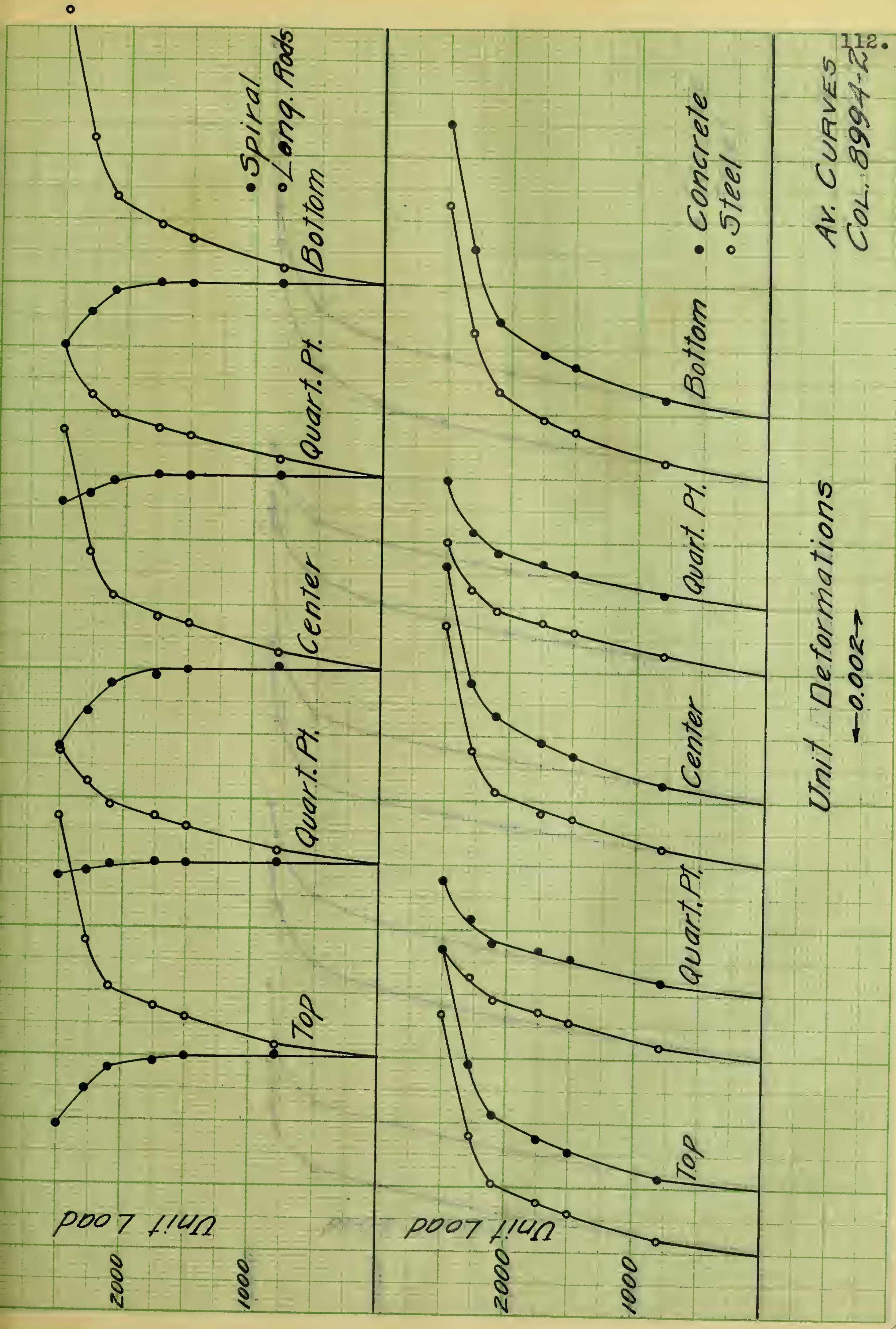


Av. Curves
Col. 8994-1



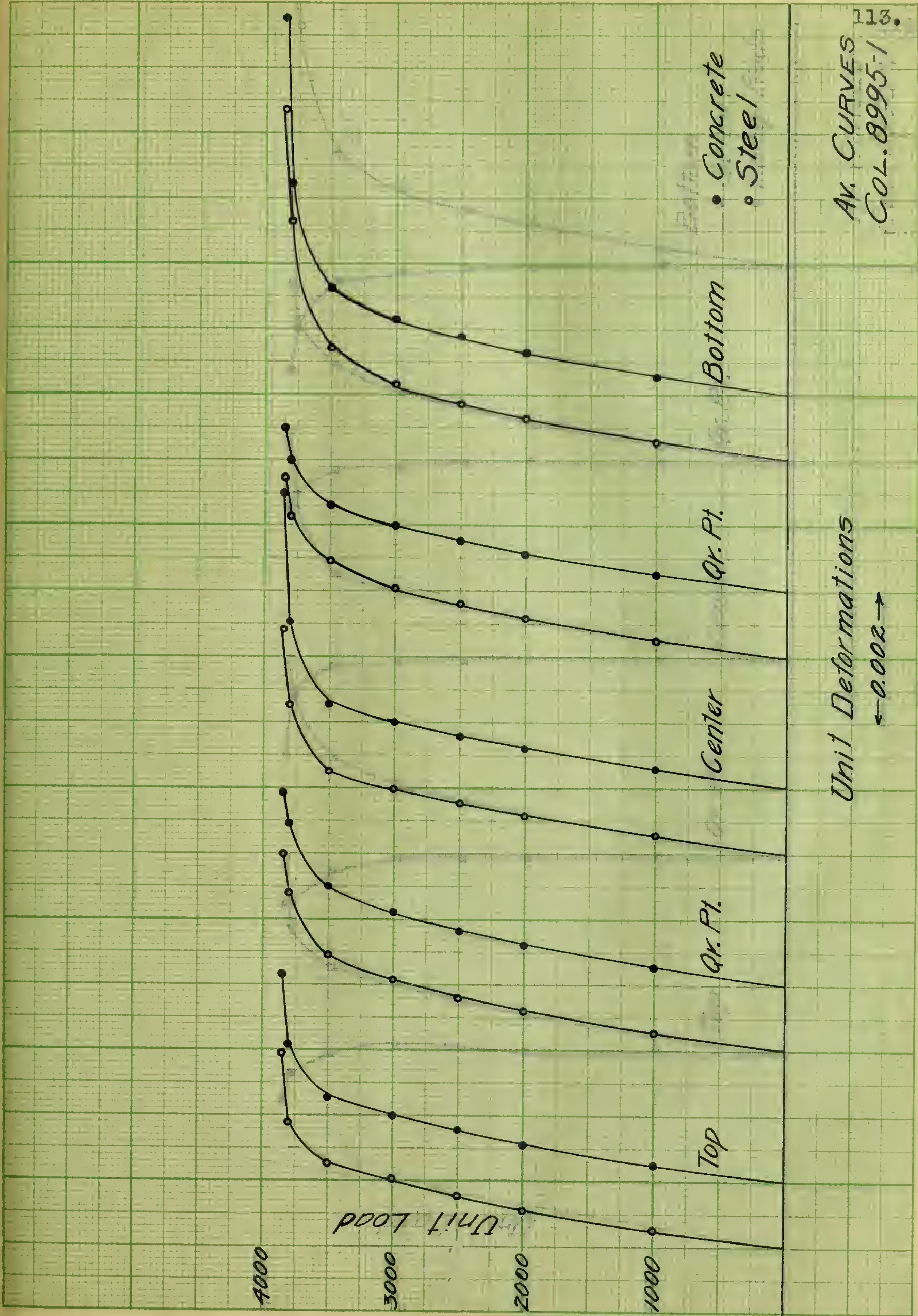
Av. CURVES
COL. 8994-1


Unit Load
2000
1000
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
• Spiral
∘ Long. Rods
Unit Load
2000
1000
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
• Concrete
∘ Steel
Unit Deformations
← 0.002 →
Av. Curves
Col. 8994-3

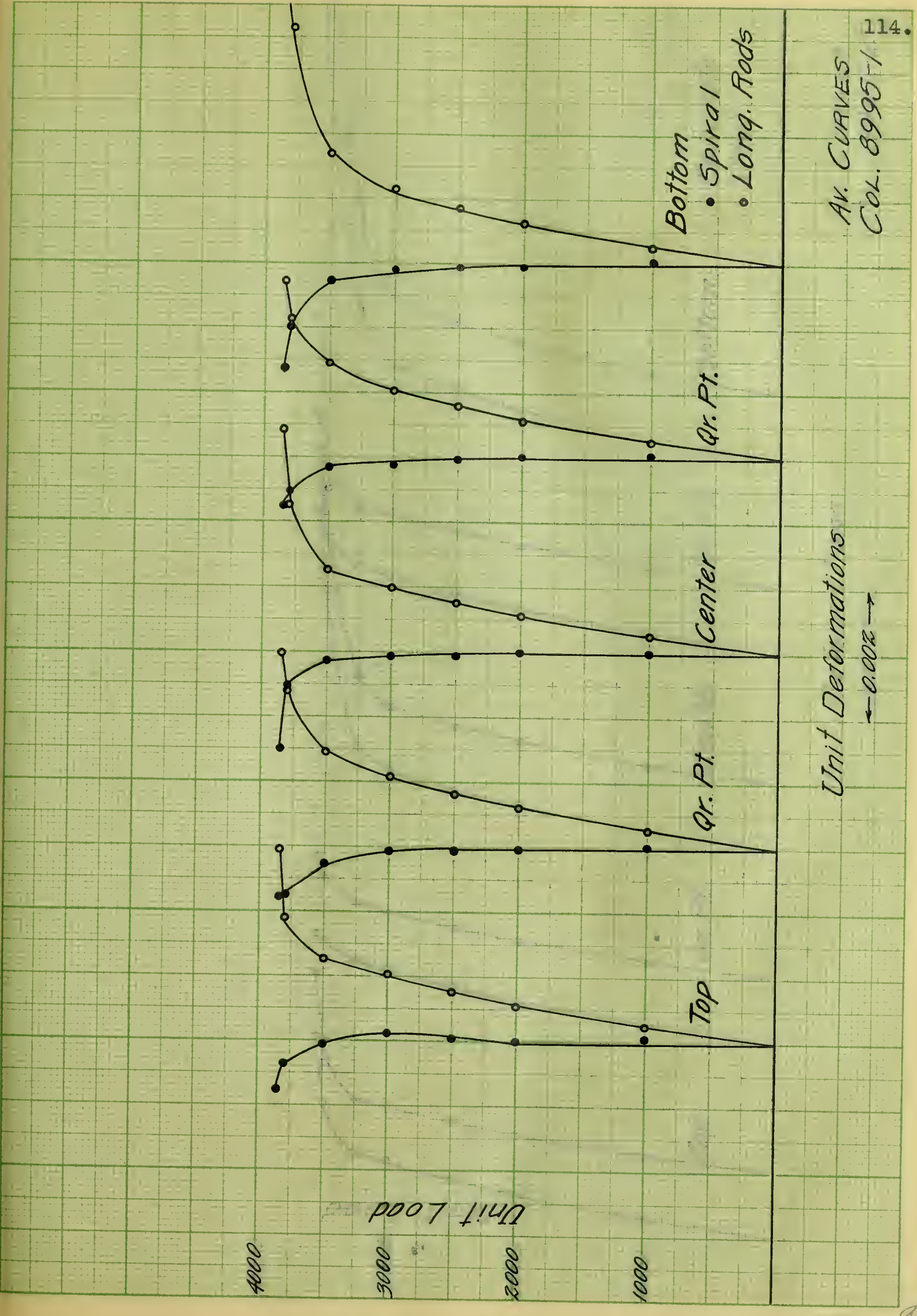


Av. CURVES
COL. 8994-Z

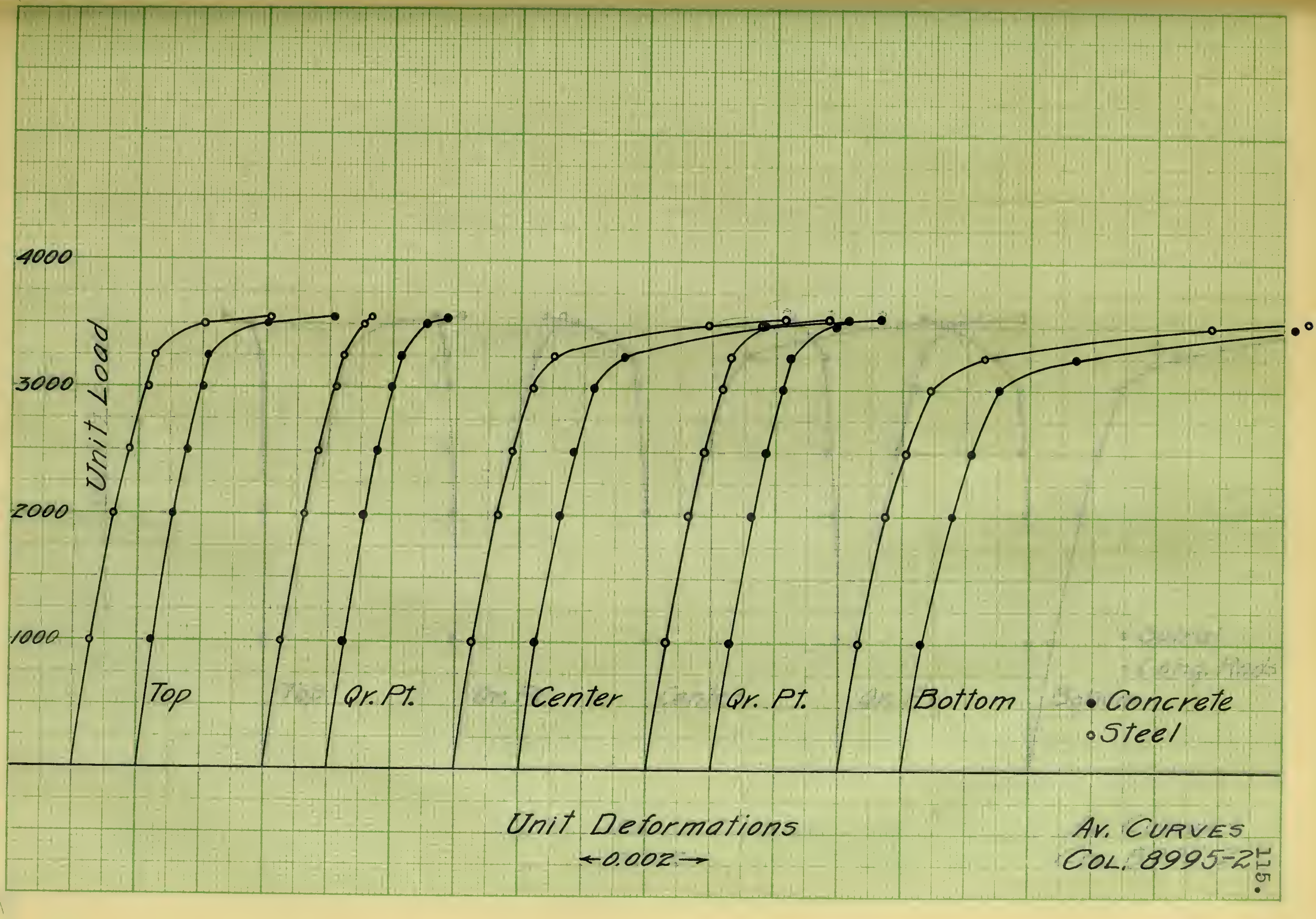
a

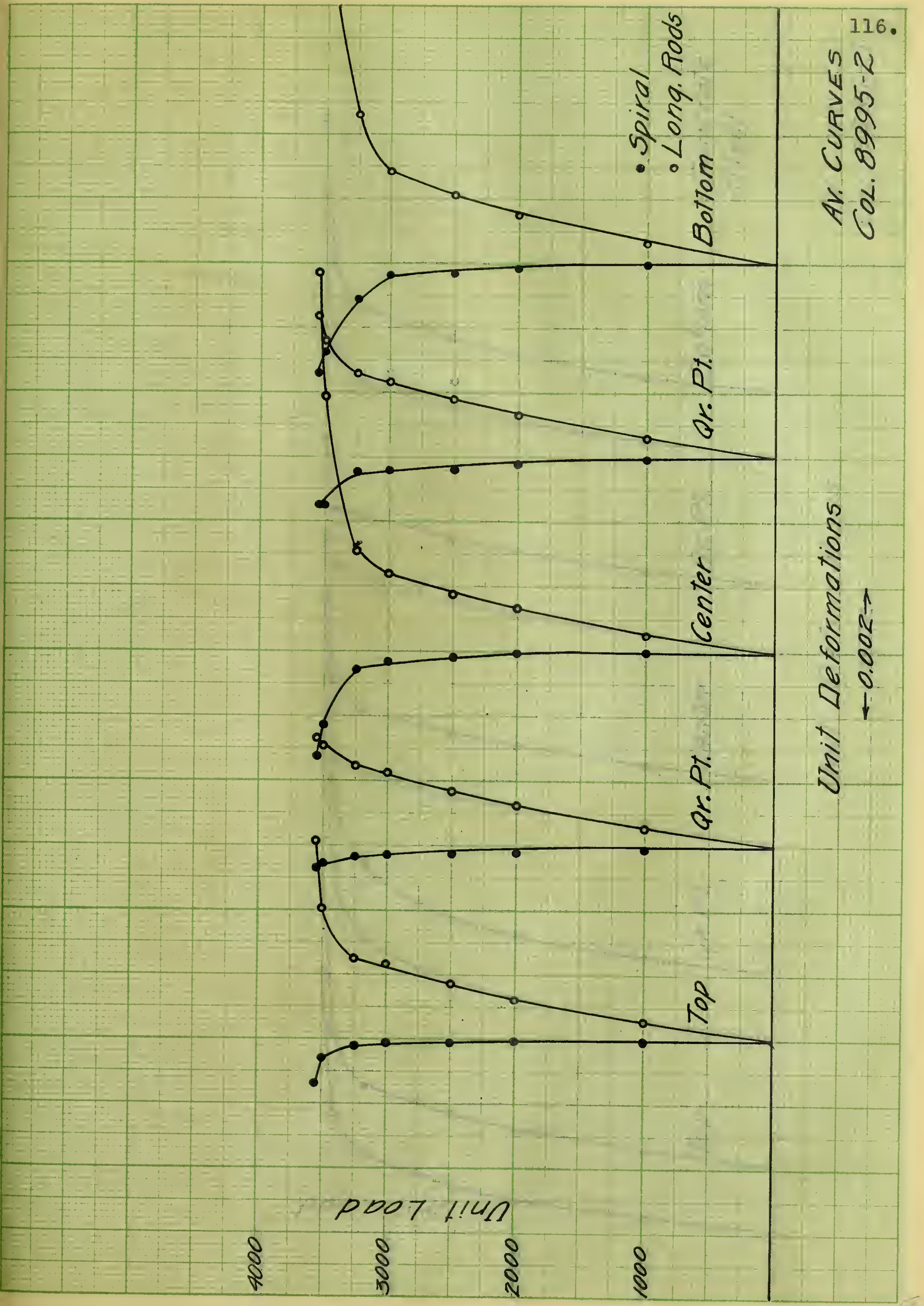


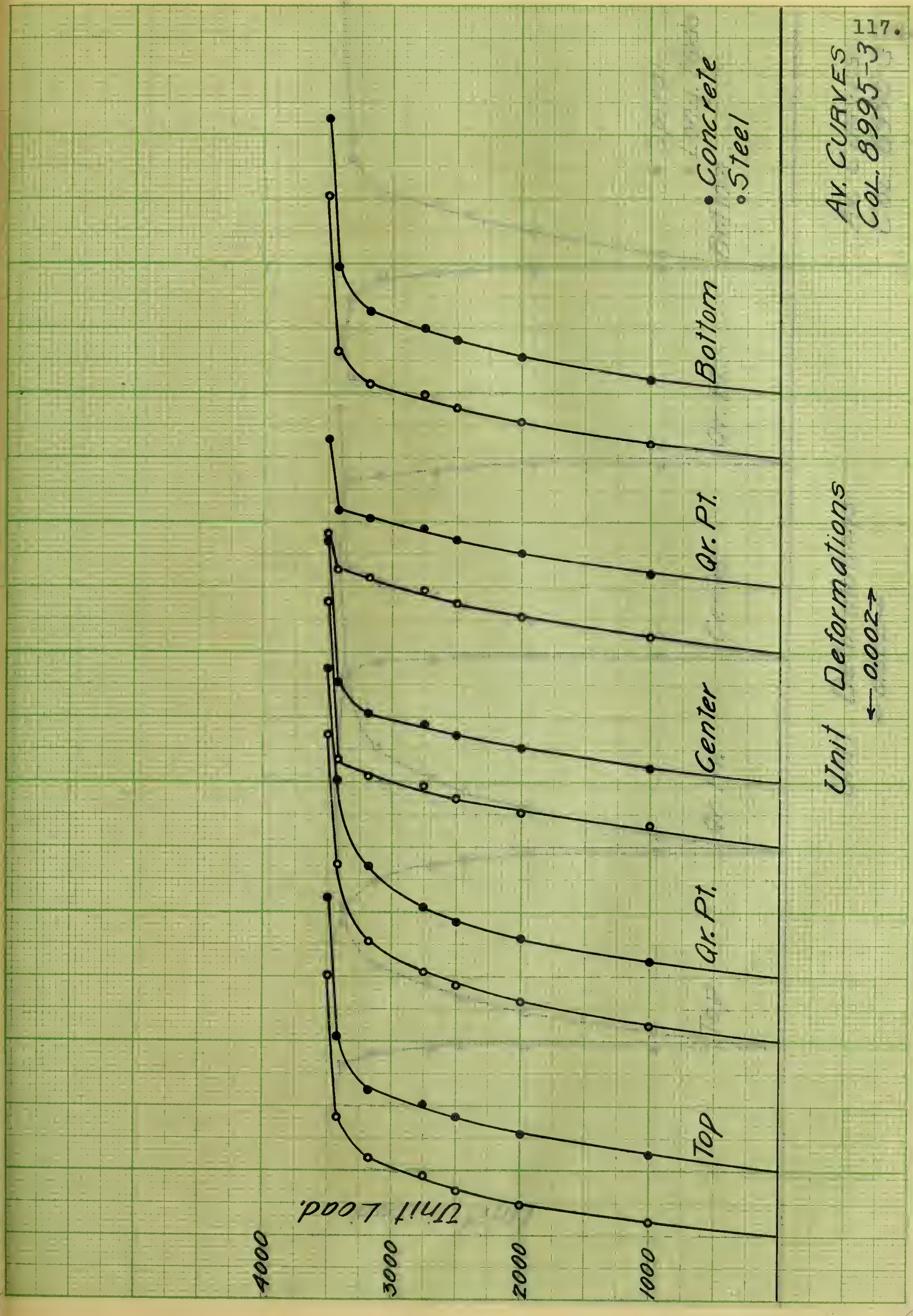
Av. CURVES
COL. 8995-1


Av. Curves
Col. 8995-1
Bottom
● Spiral
○ Long. Rods
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
← 0.002 →
Unit Load
4000
3000
2000
1000

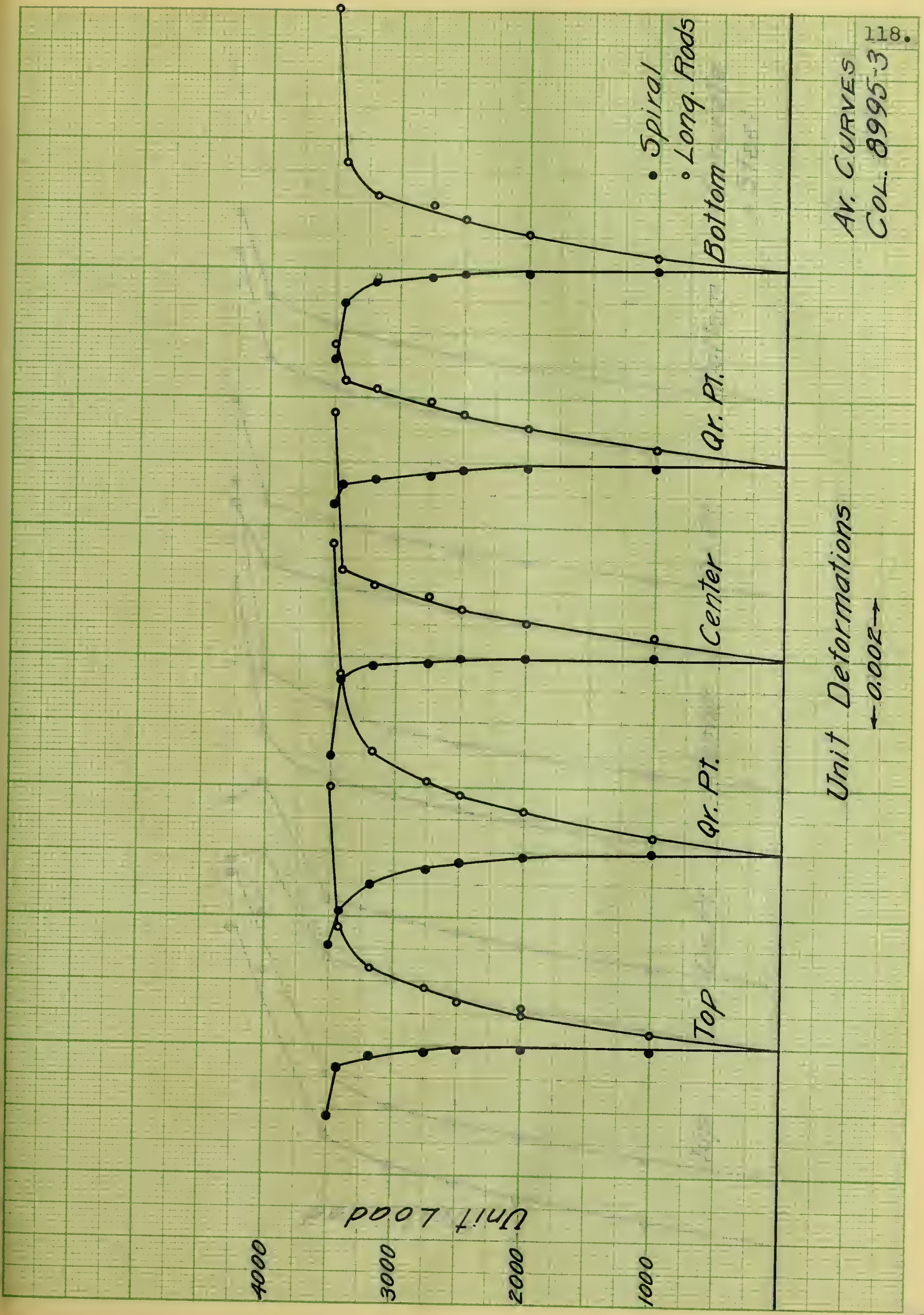
a

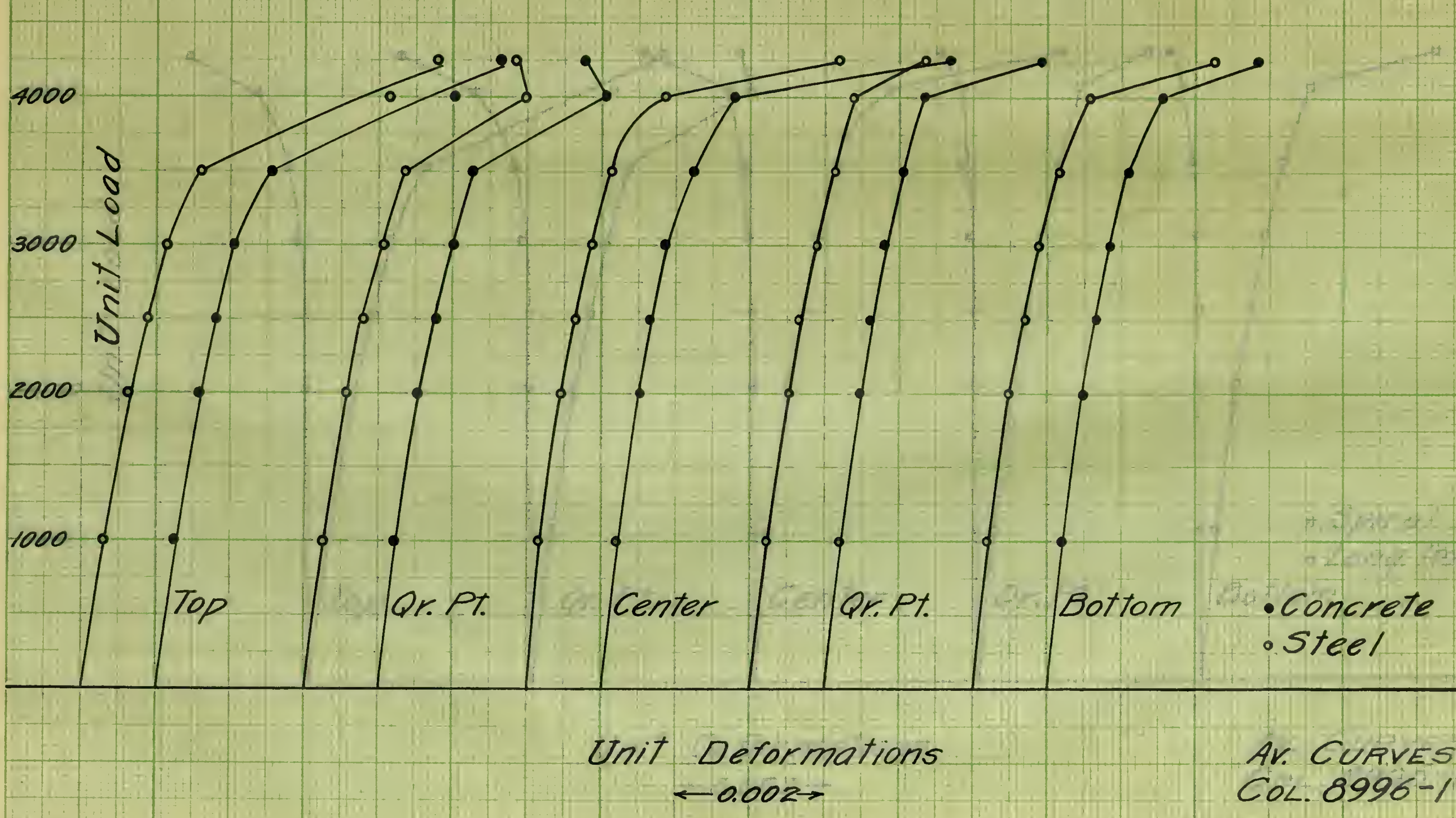

4000
3000
2000
1000
Unit Load
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
● Concrete
○ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8995-2


Av. CURVES
COL. 8995-2

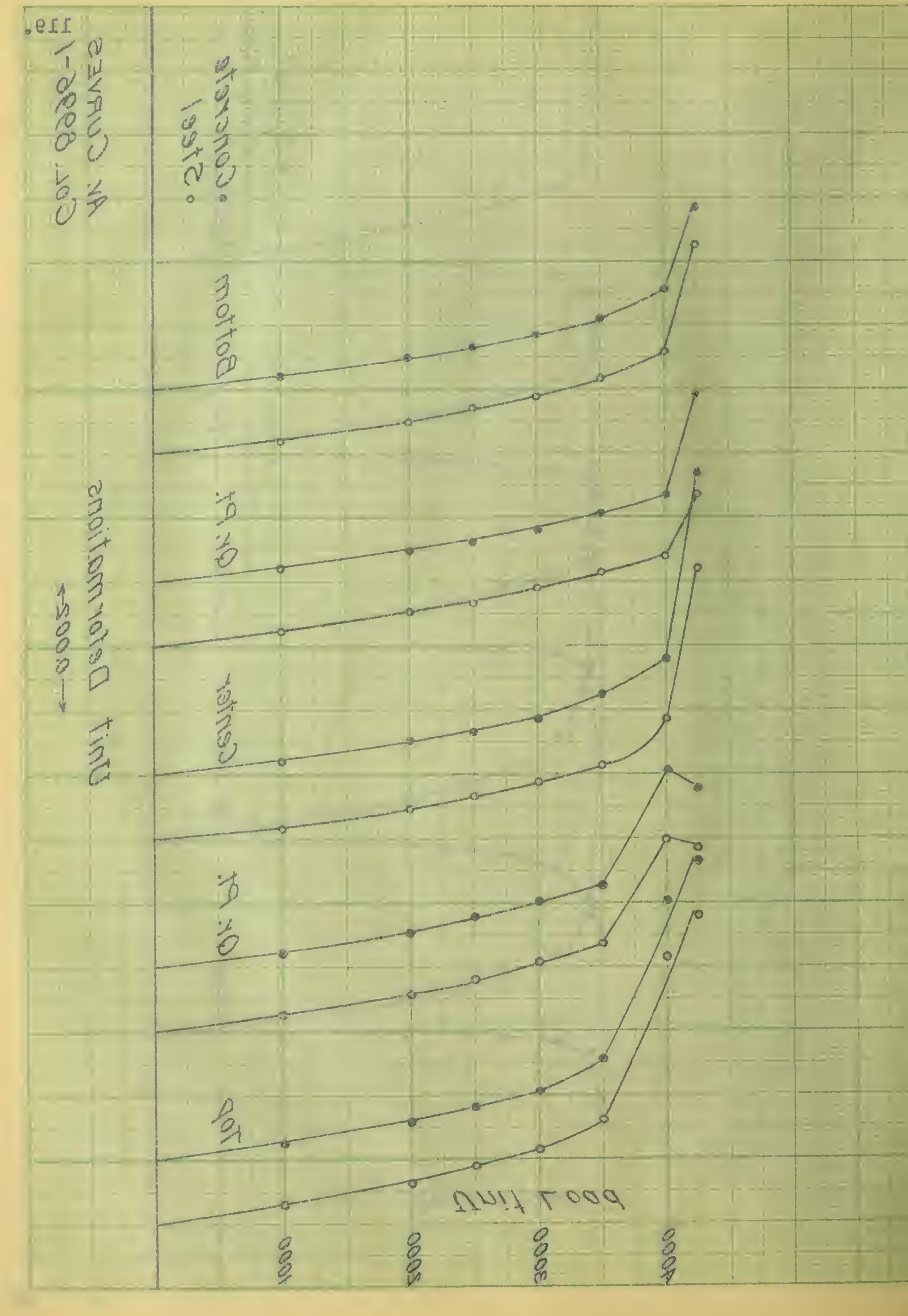

Av. CURVES
COL. 8995-3
● Concrete
○ Steel
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Load.
4000
3000
2000
1000
Unit Deformations
←0.002→

a.

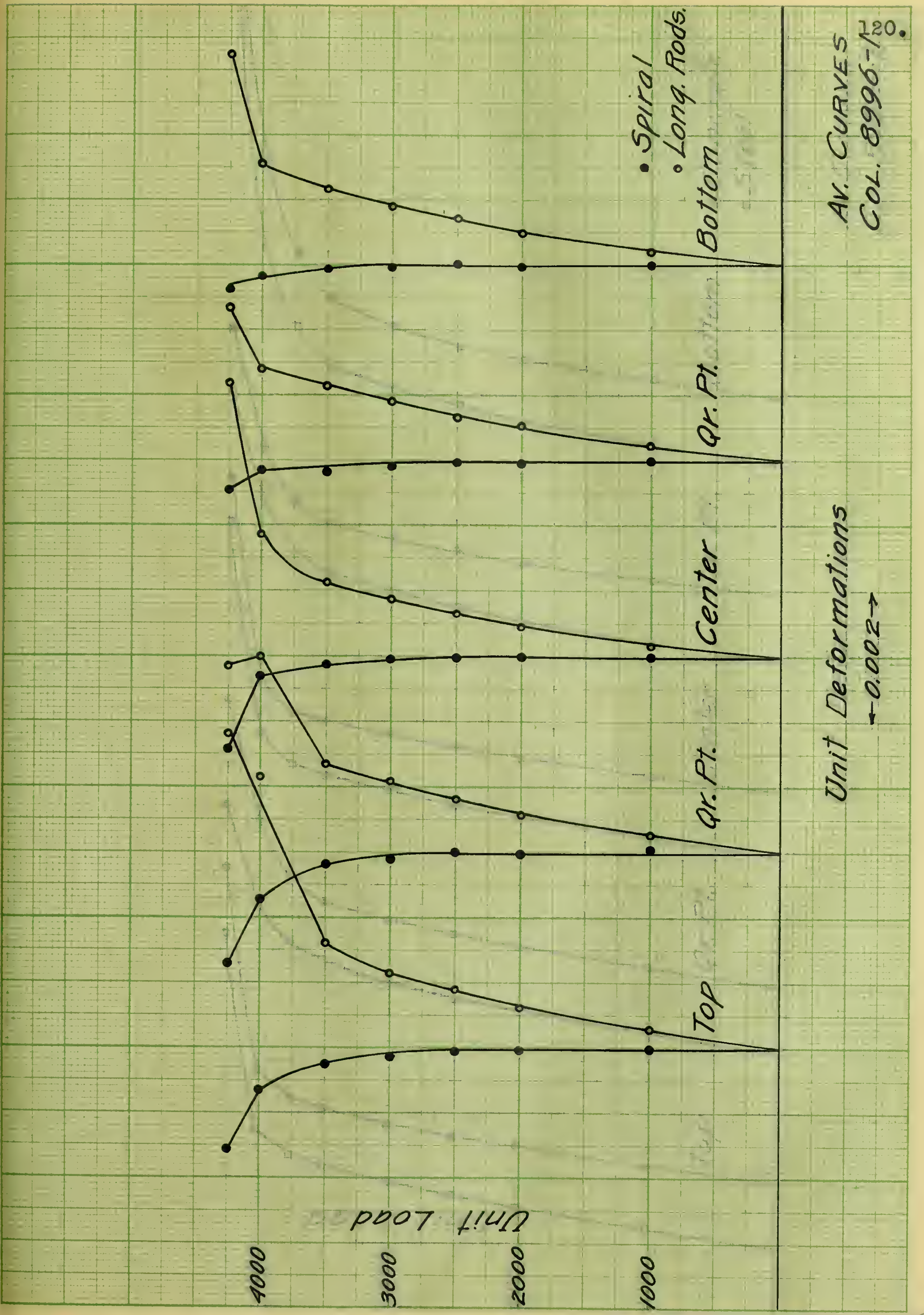

● Spiral
○ Long. Rods
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Av. CURVES
COL. 8995-3
Unit Deformations
←0.002→
Unit Load
4000
3000
2000
1000


Unit Load
4000
3000
2000
1000
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8996-1

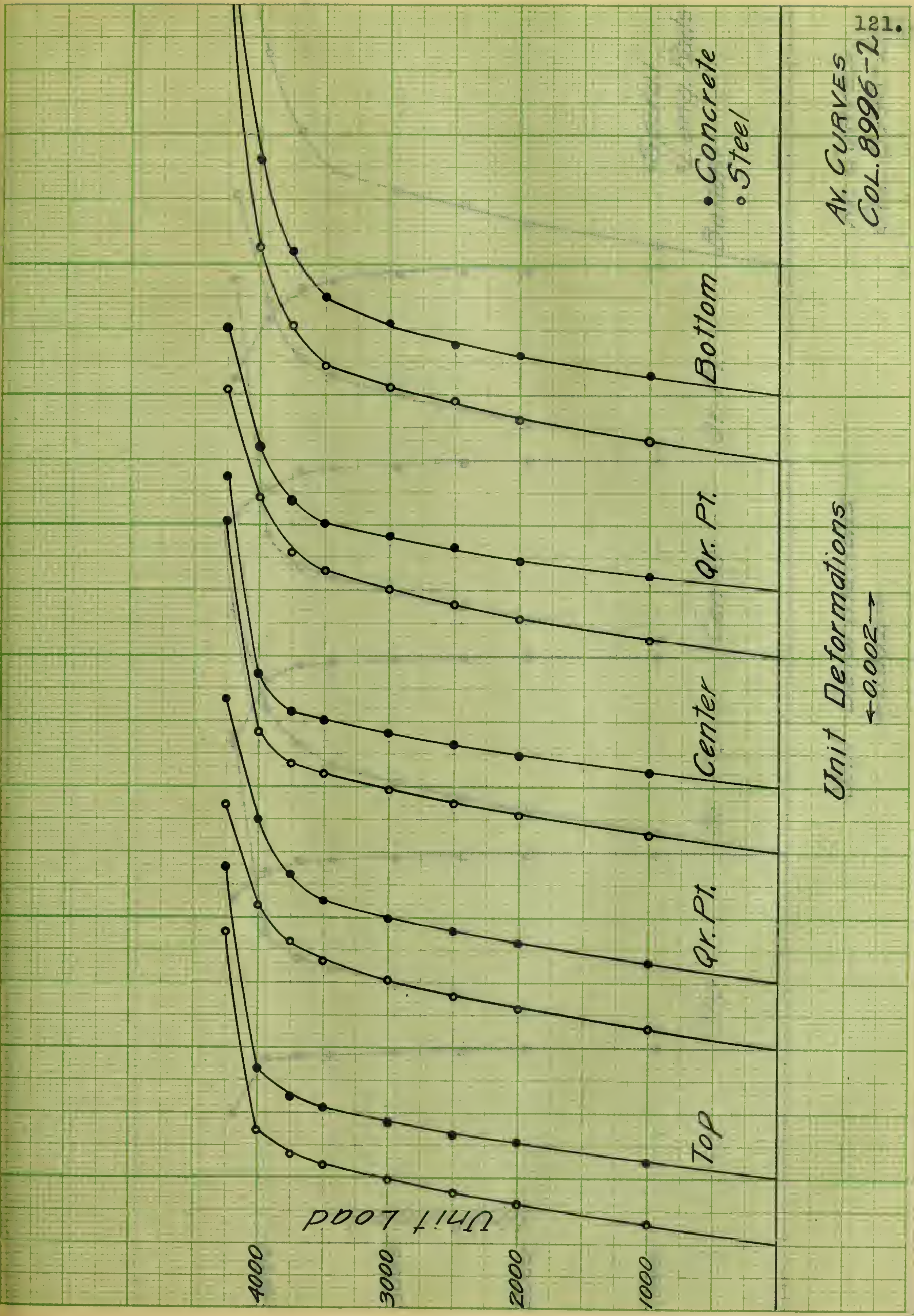
129.

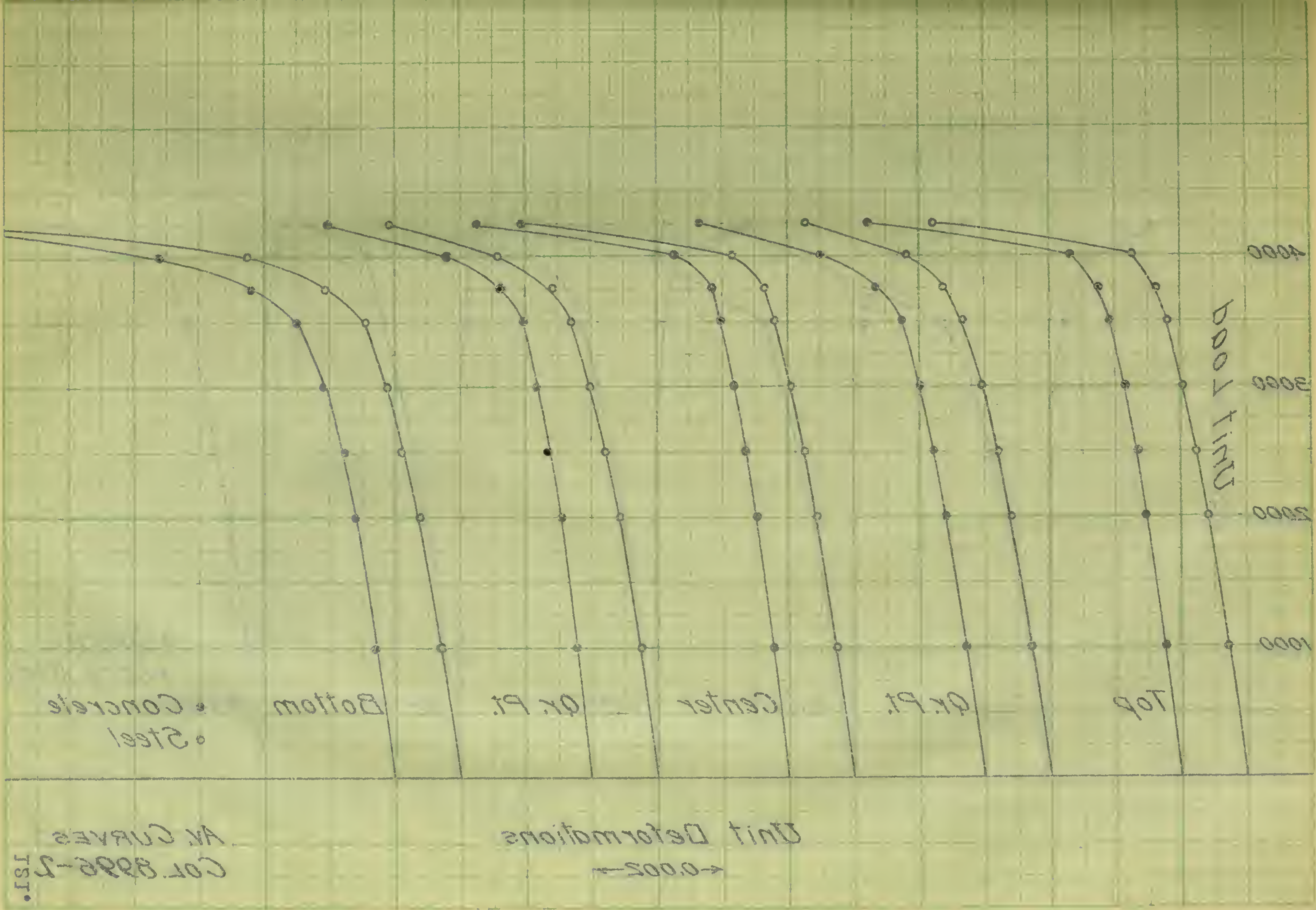


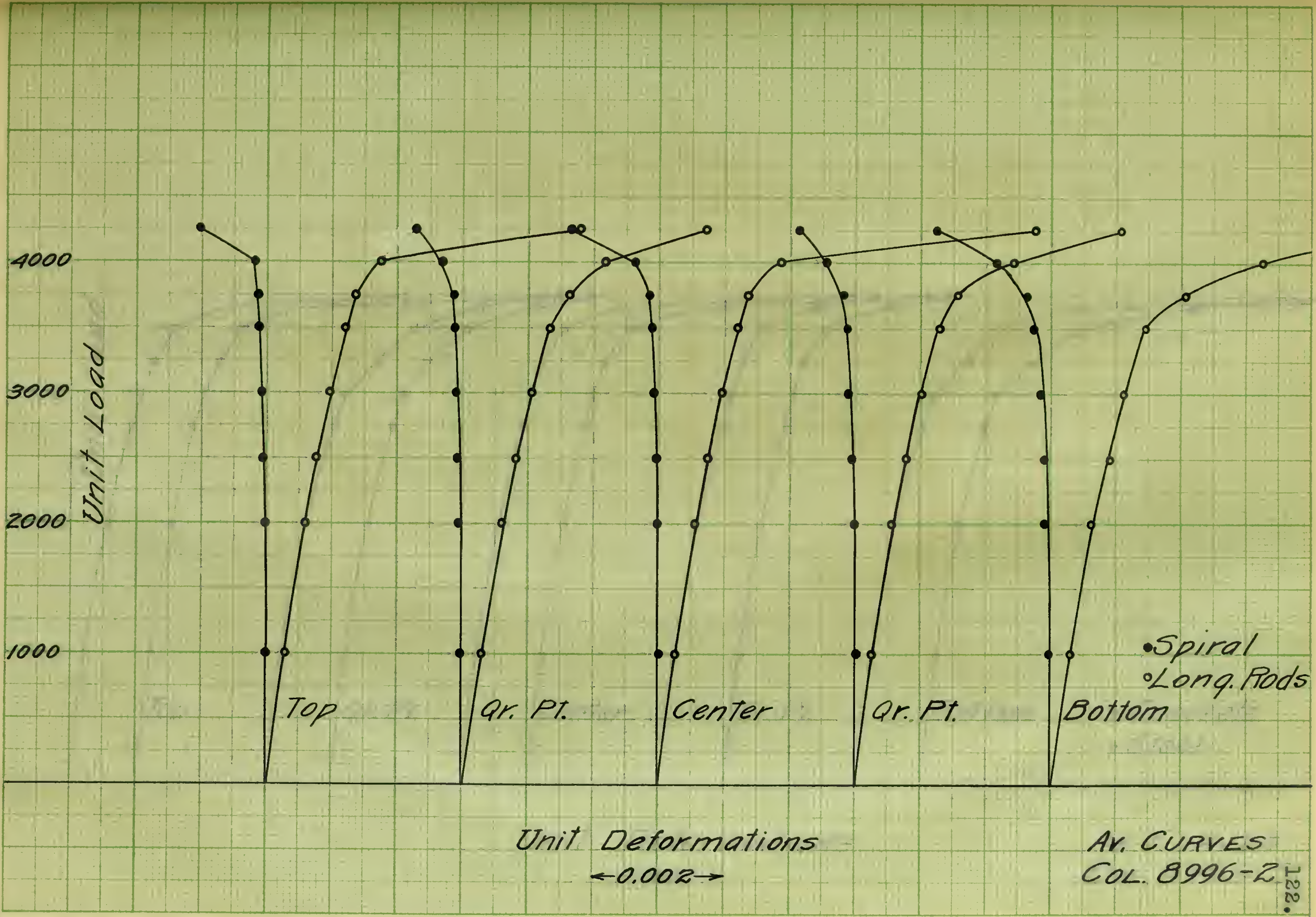
Av. Curves
Col. 9956-1
● Concrete
○ Steel
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
←.0002→
Unit Load
1000
2000
3000
4000

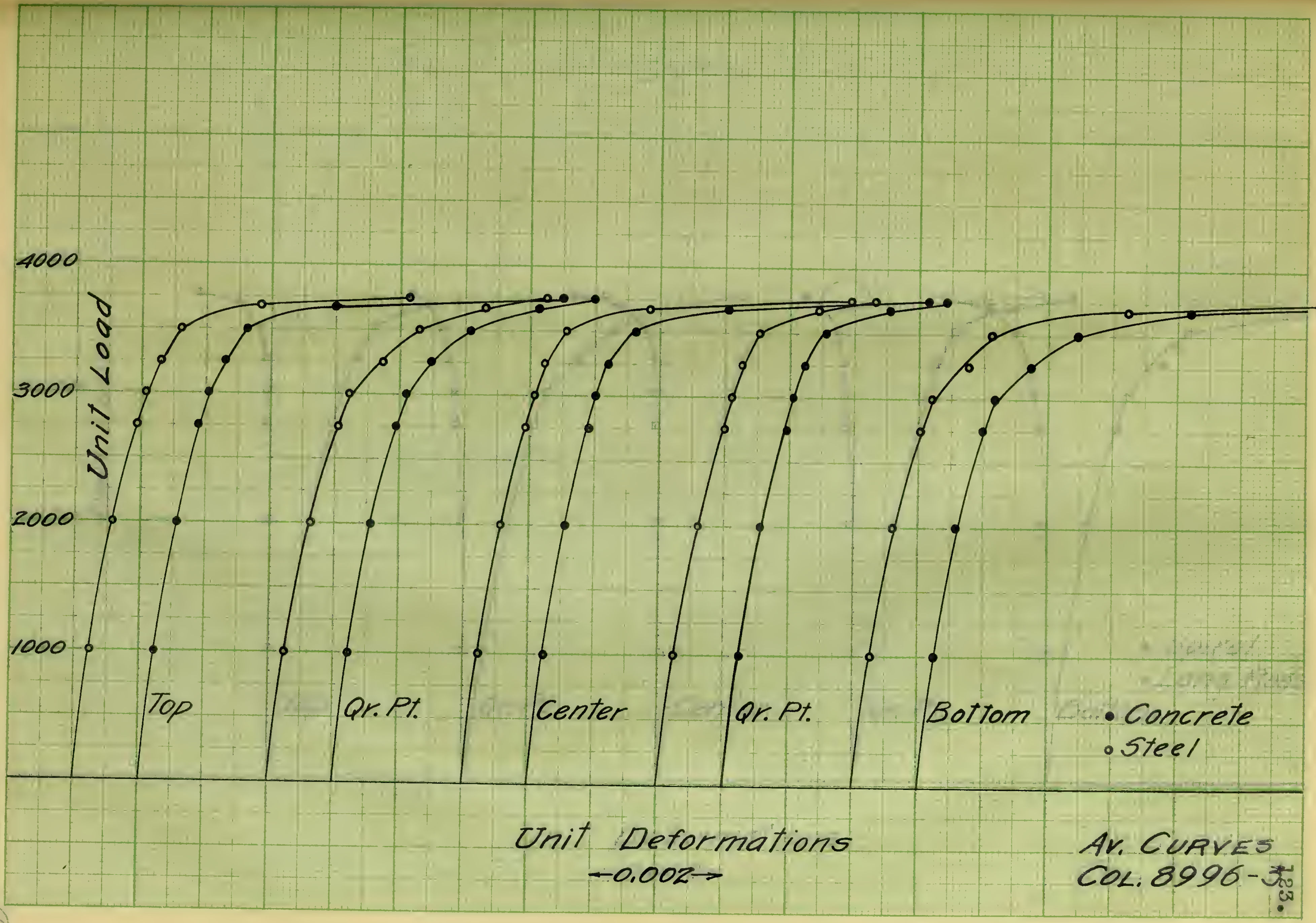


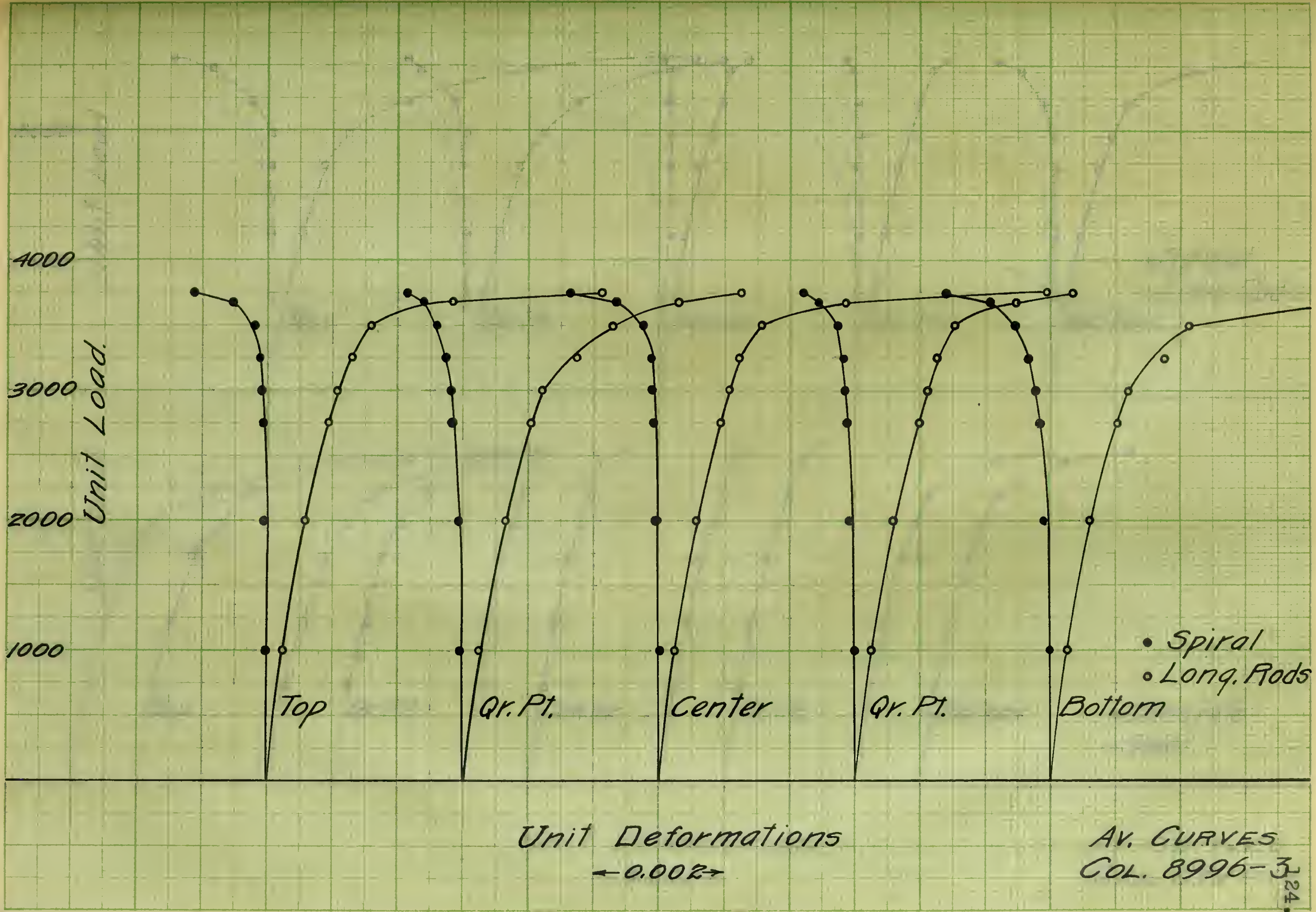
Av. Curves
Col. 8996-1


Av. Curves
Col. 8996-2
● Concrete
○ Steel
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
←0.002→
Unit Load
4000
3000
2000
1000

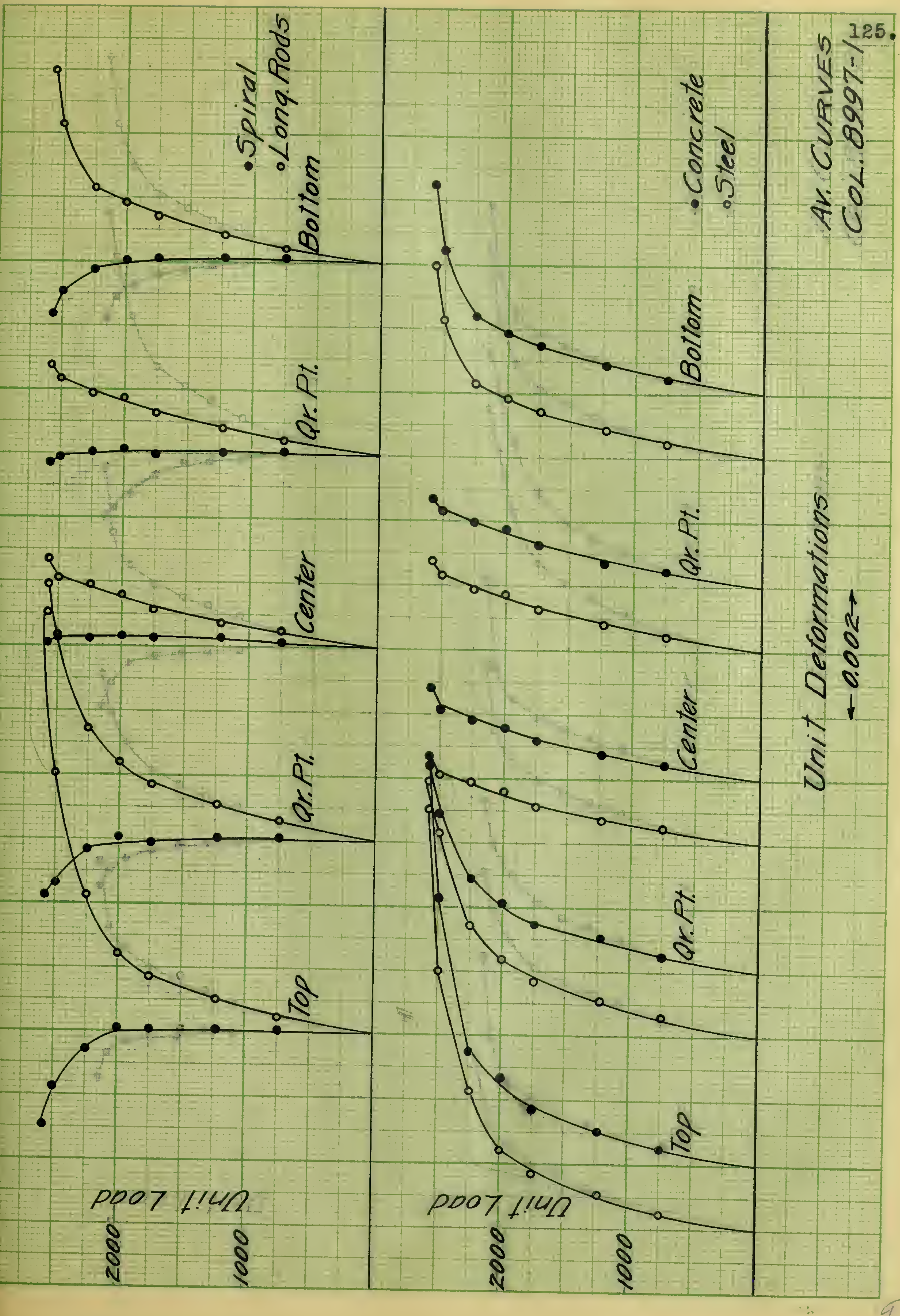

121.
Ak Curves
Col. 8996-2
Unit Deformations
←0.002→
Unit Load
1000
2000
3000
4000
• Concrete
◦ Steel
Bottom
Qr. Pt.
Center
Qr. Pt.
Top

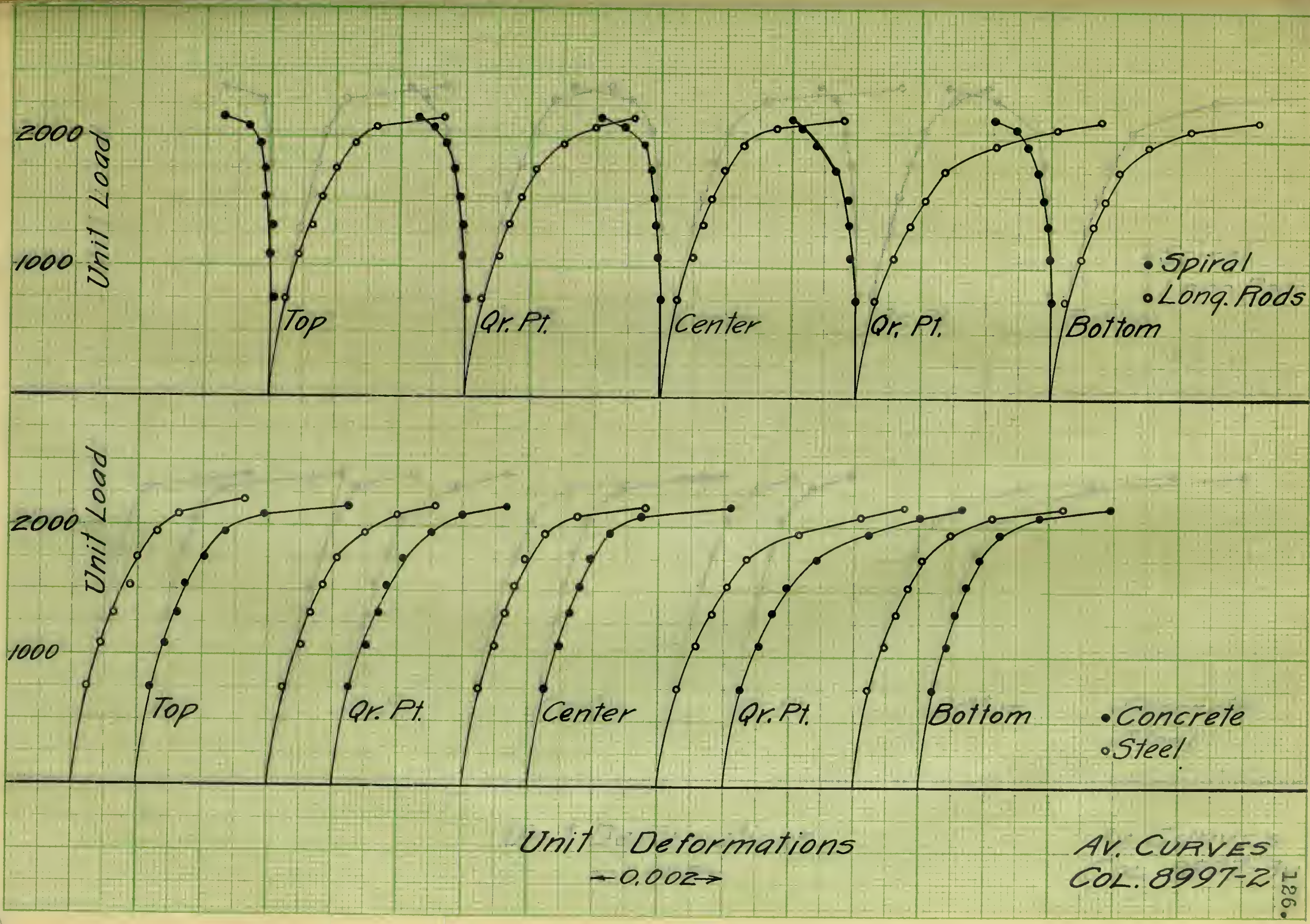

4000
3000
2000
1000
Unit Load
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
•Spiral
°Long. Rods
Unit Deformations
←0.002→
Av. CURVES
Col. 8996-2

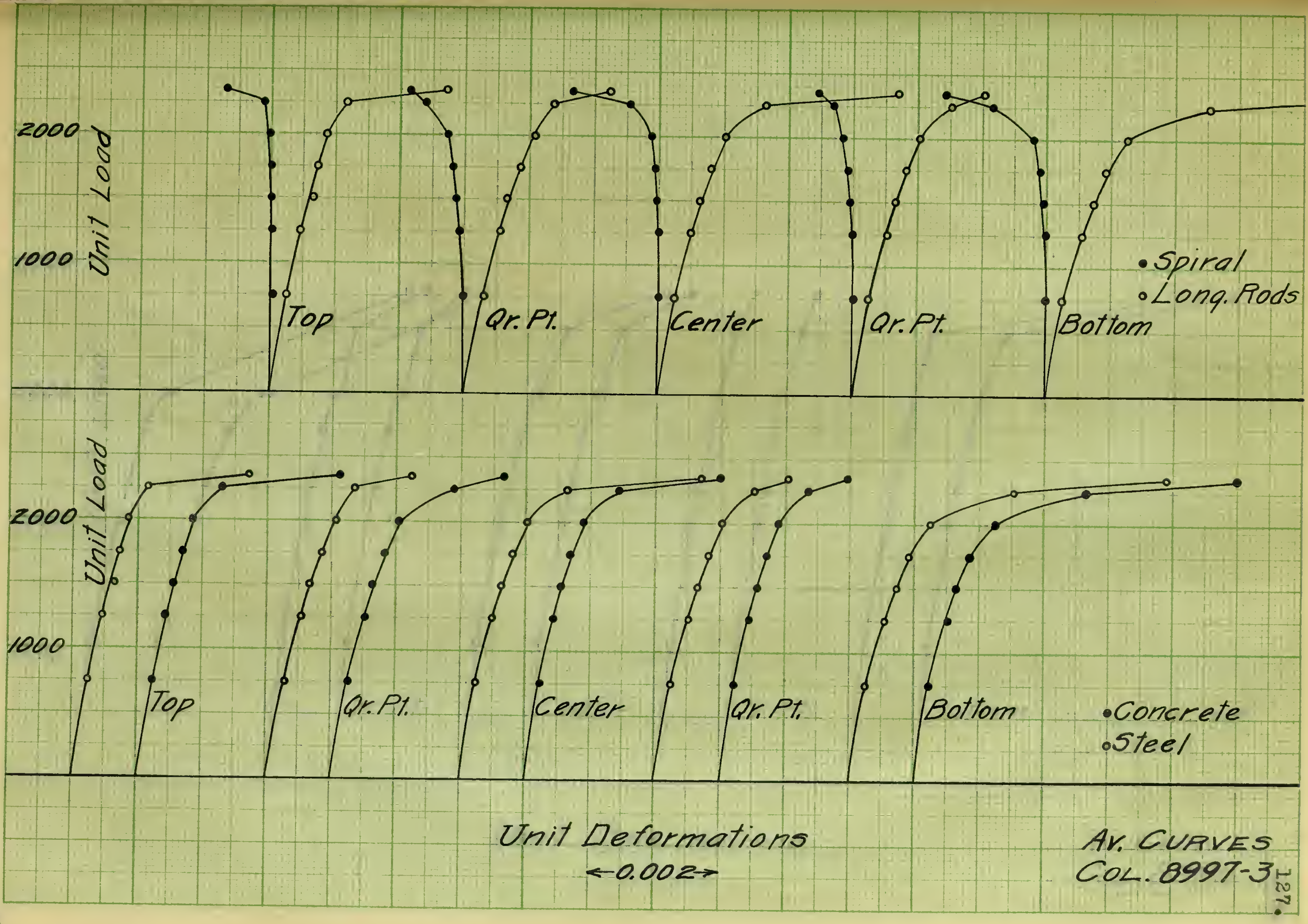

4000
3000
2000
1000
Unit Load
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
● Concrete
○ Steel
Unit Deformations
←0.002→
Av. Curves
Col. 8996-5



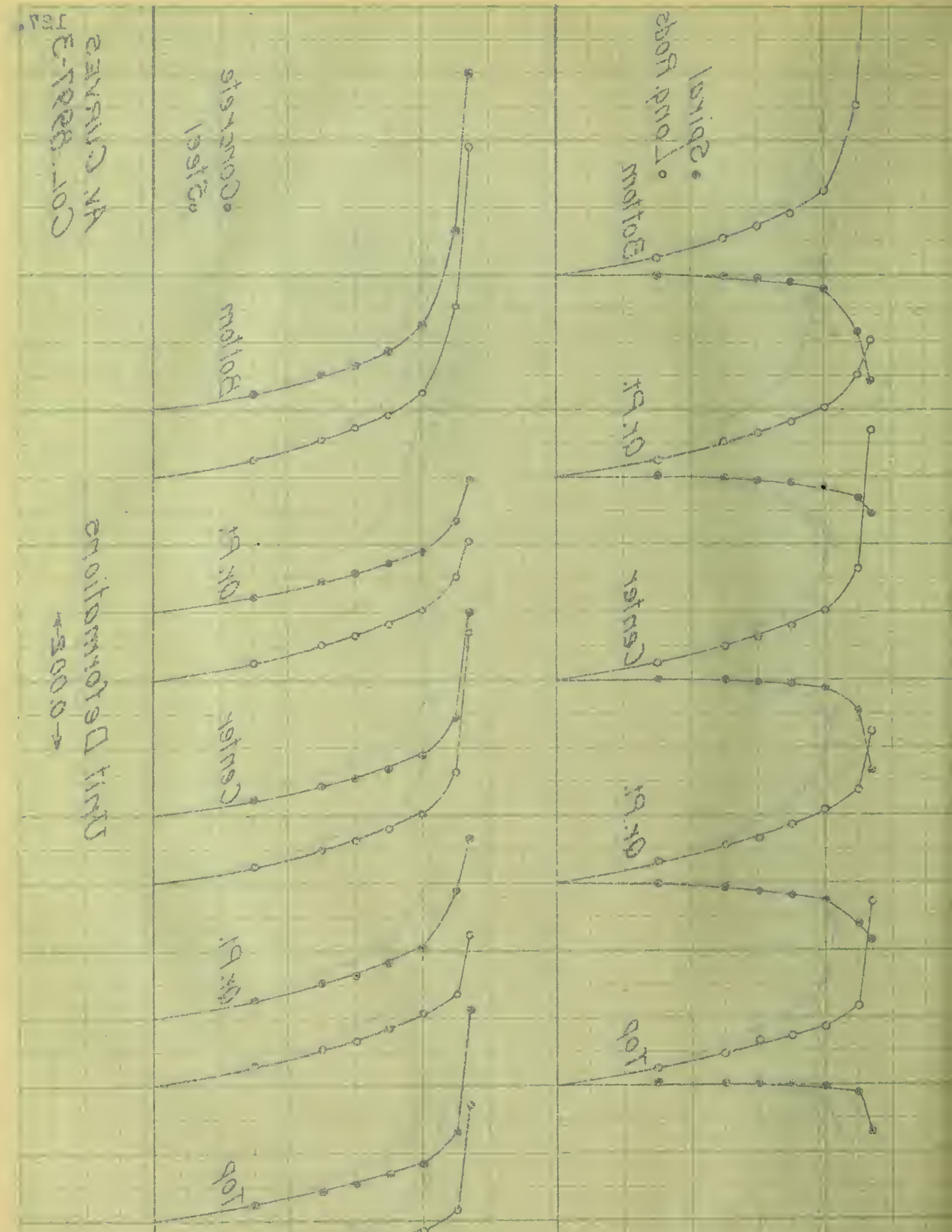
Av. CURVES
Col. 8996-3


Av. CURVES
COL. 8997-1
• Spiral
∘ Long. Rods
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Load
2000
1000
• Concrete
∘ Steel
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Load
2000
1000
Unit Deformations
← 0.002 →

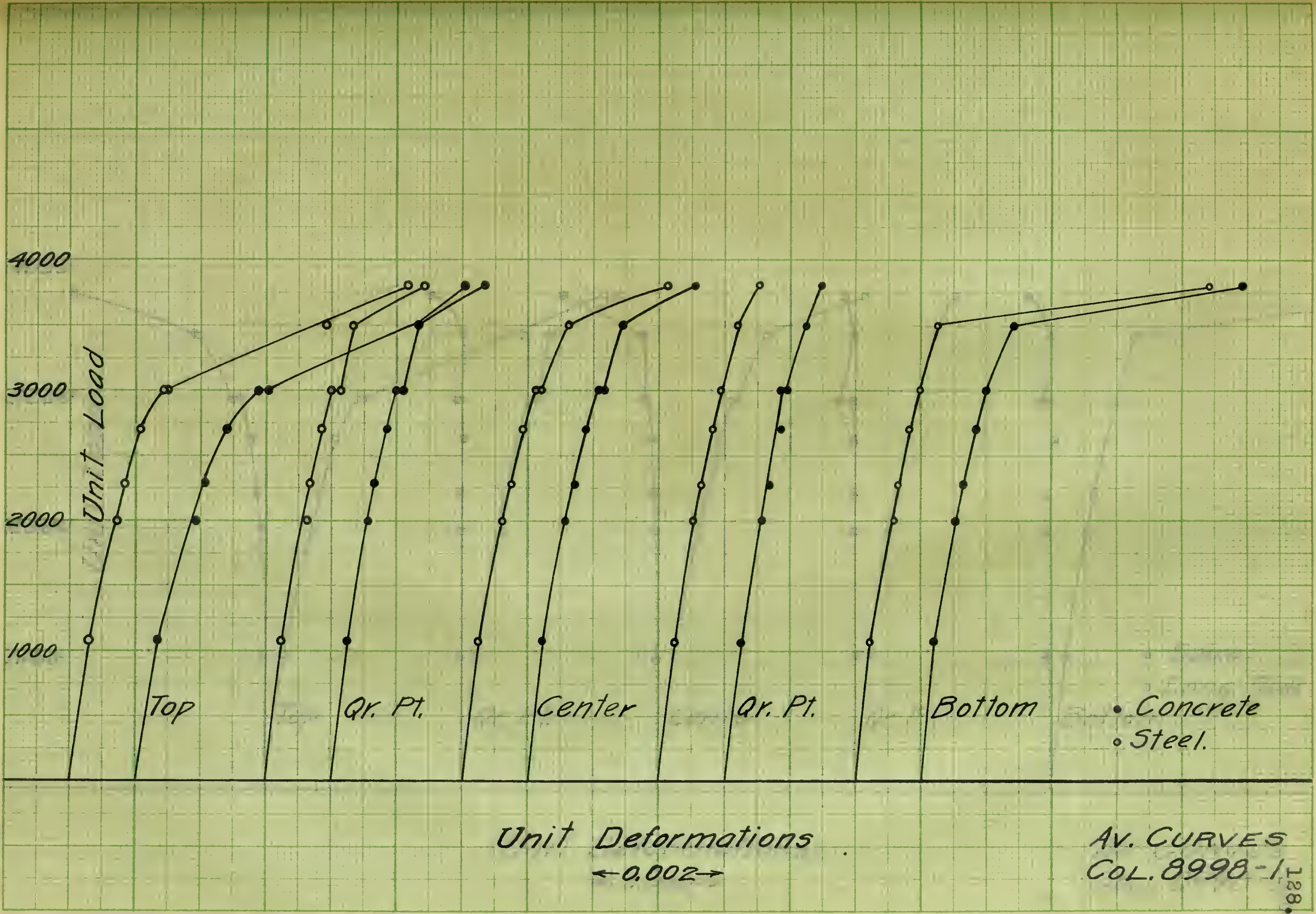

2000
1000
Unit Load
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
• Spiral
∘ Long. Rods
2000
1000
Unit Load
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
• Concrete
∘ Steel
Unit Deformations
←0.002→
Av. CURVES
COL. 8997-2

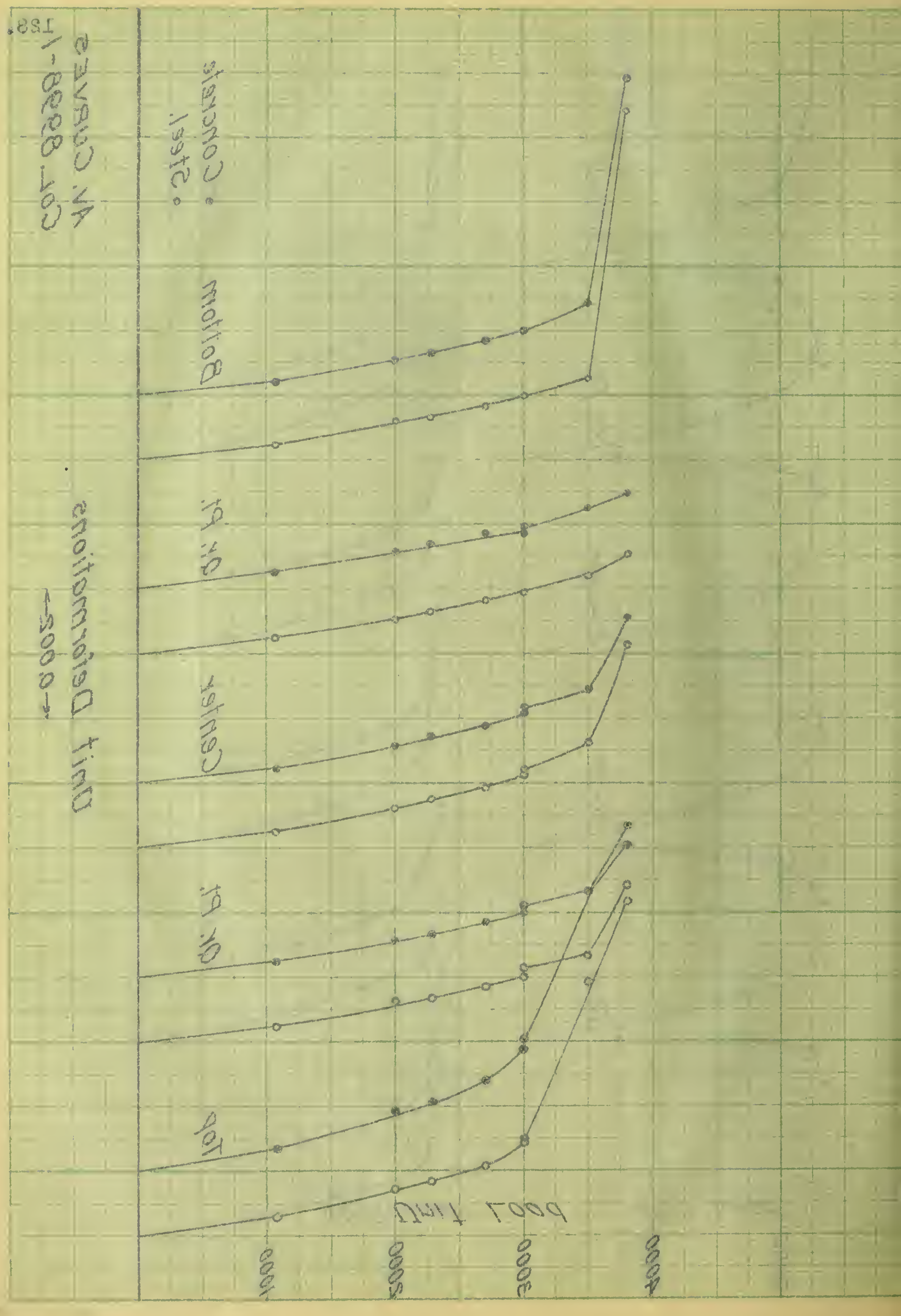


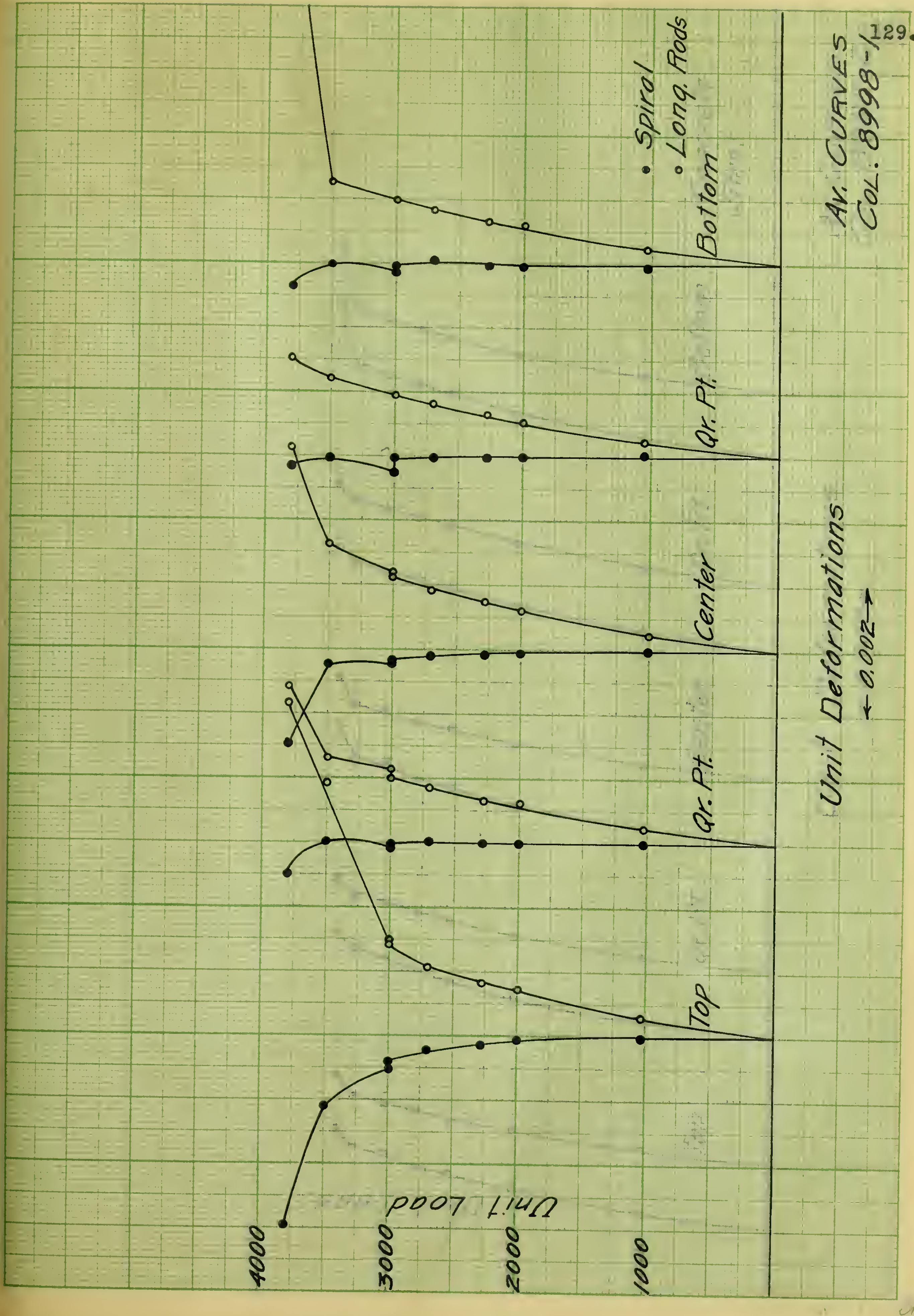
AV. CURVES
COL. 8997-3



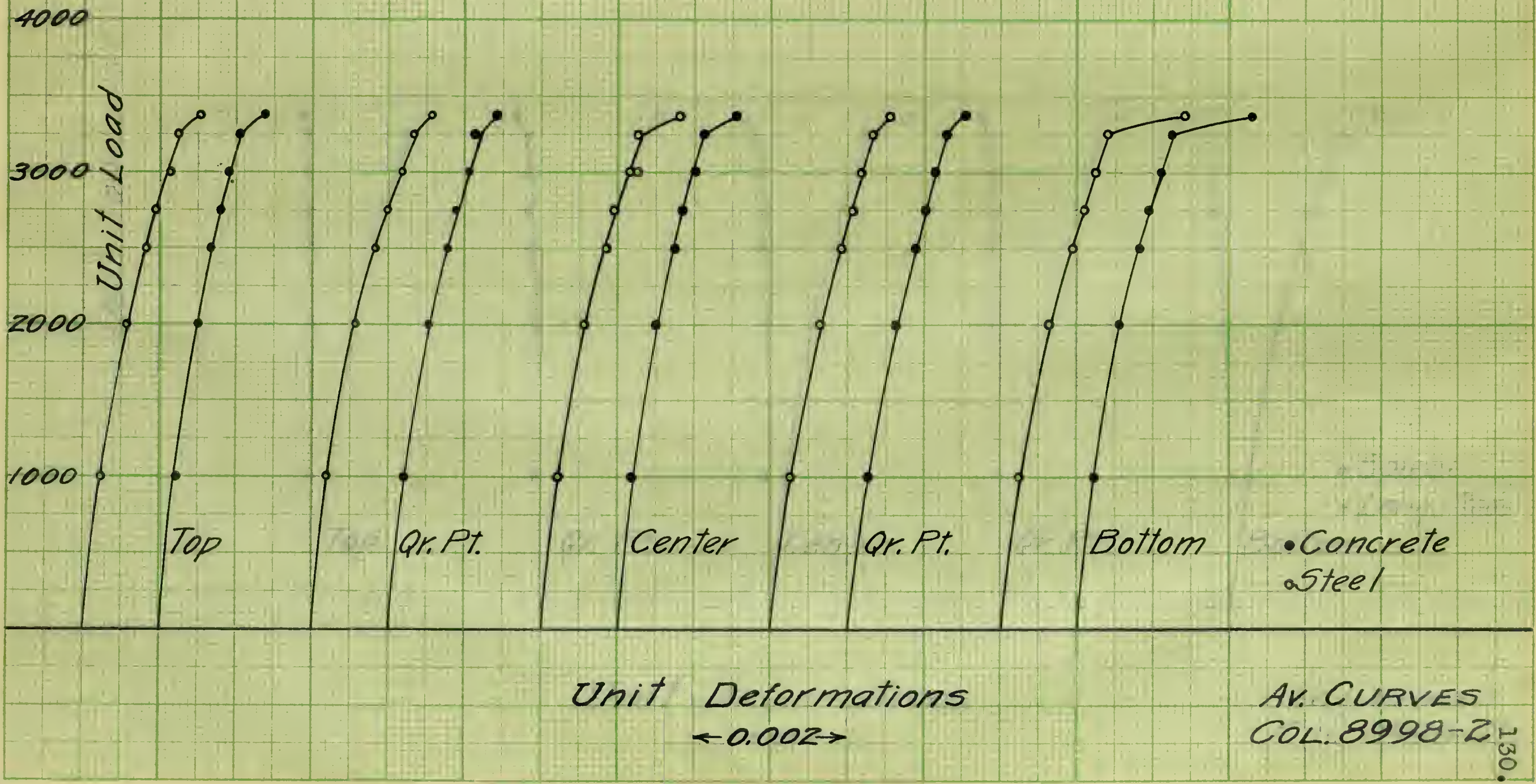
157
Col-88R7-3
Av. Curves
Concrete
Steel
Spiral
Long. Rods
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
0.0002→
Load Unit
1000
2000

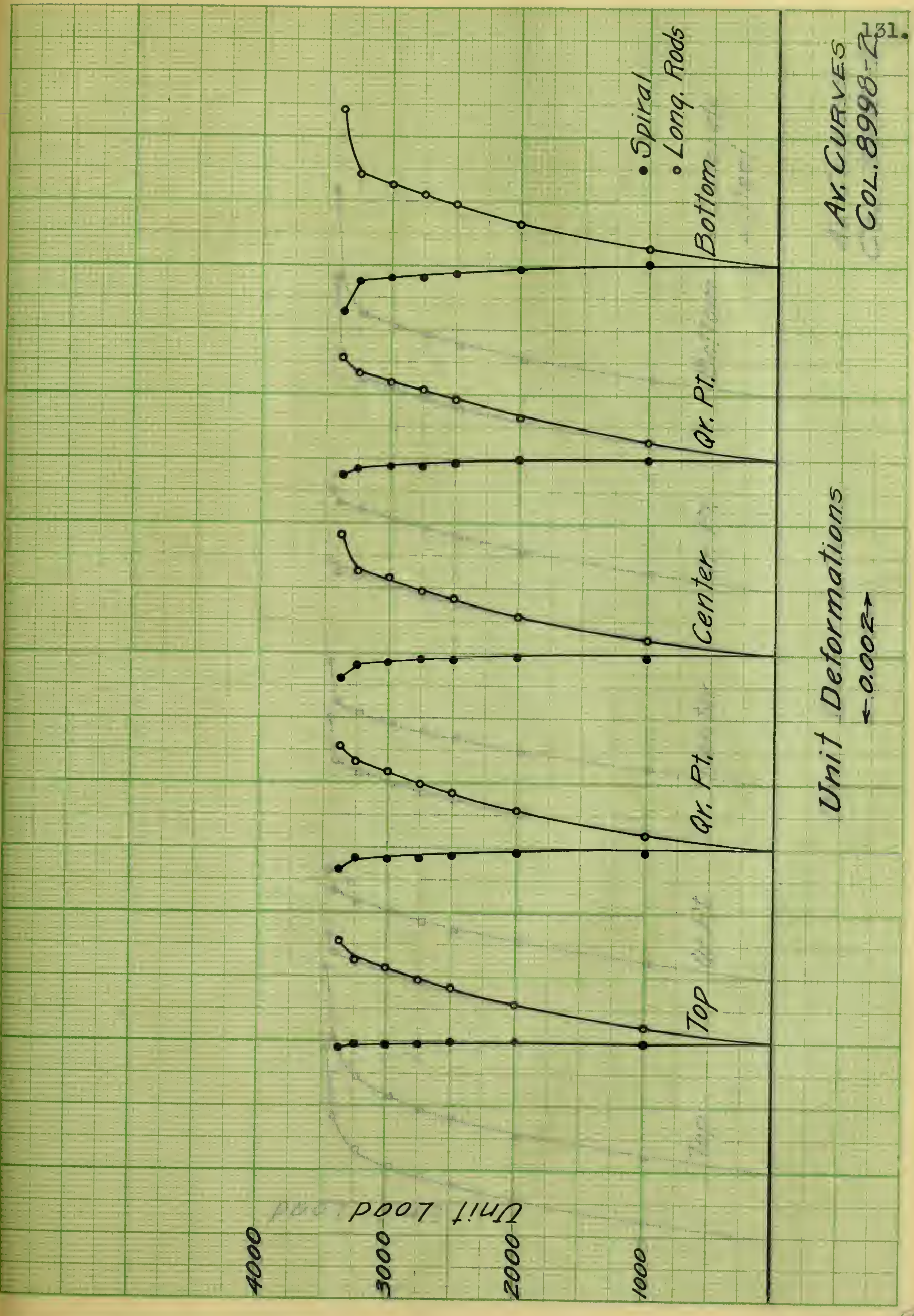

4000
3000
2000
1000
Unit Load
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
• Concrete
∘ Steel.
Unit Deformations
←0.002→
Av. Curves
Col. 8998-1

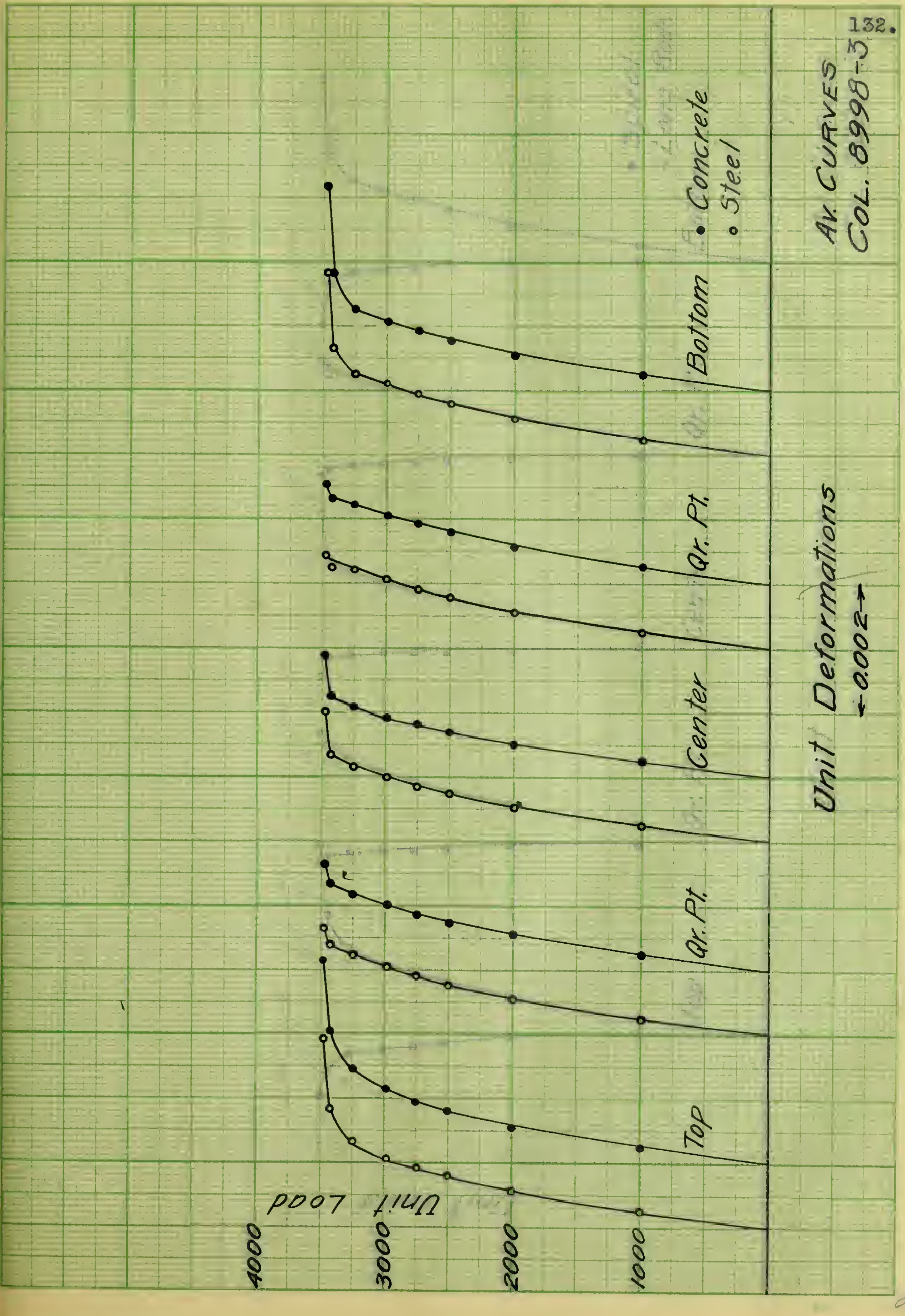

128.
Av. Curves
Col. 8598-1/-
• Concrete
◦ Steel
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
←0.0002→
Unit Load
1000
2000
3000
4000

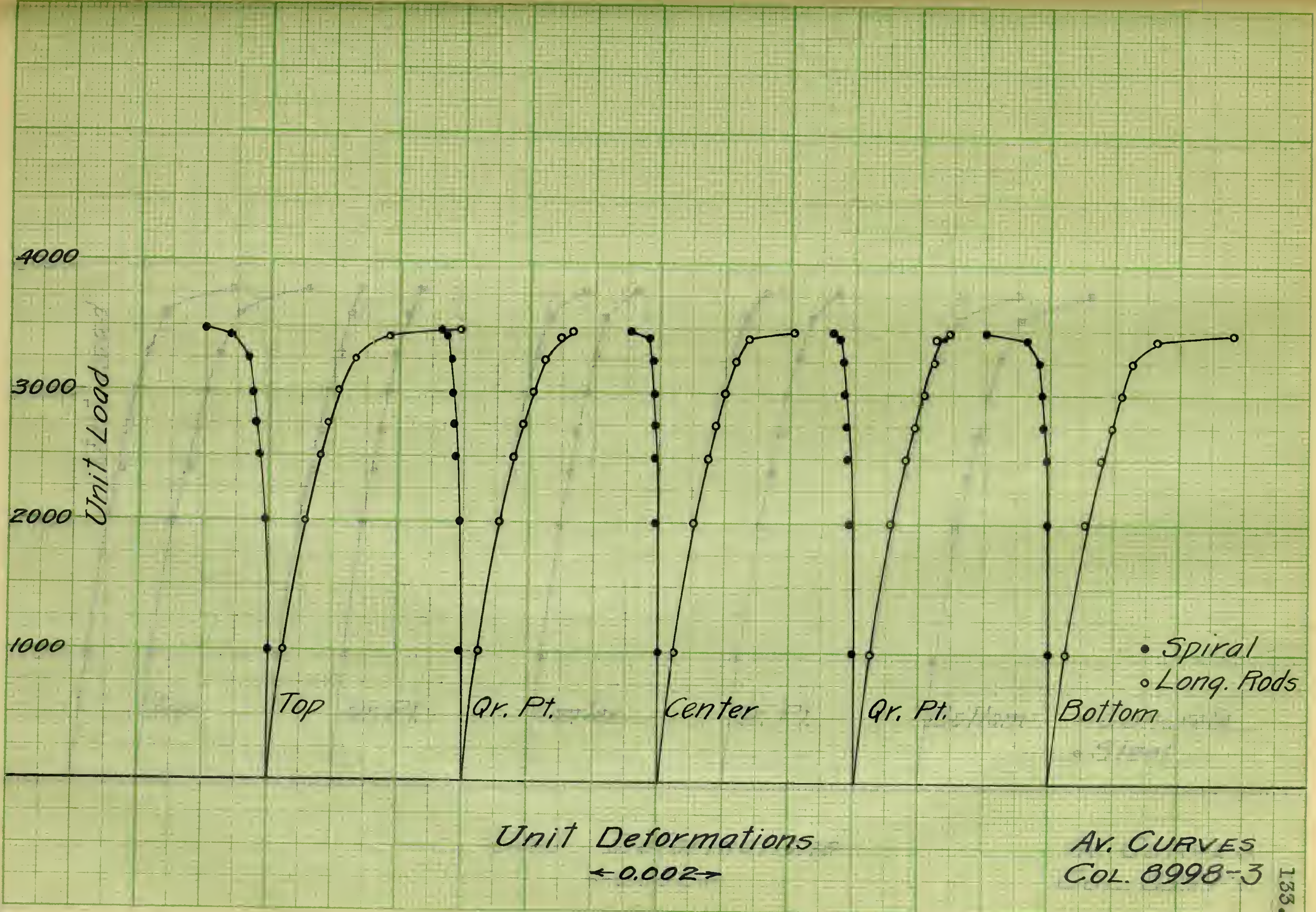


Av. CURVES
COL. 8998-1

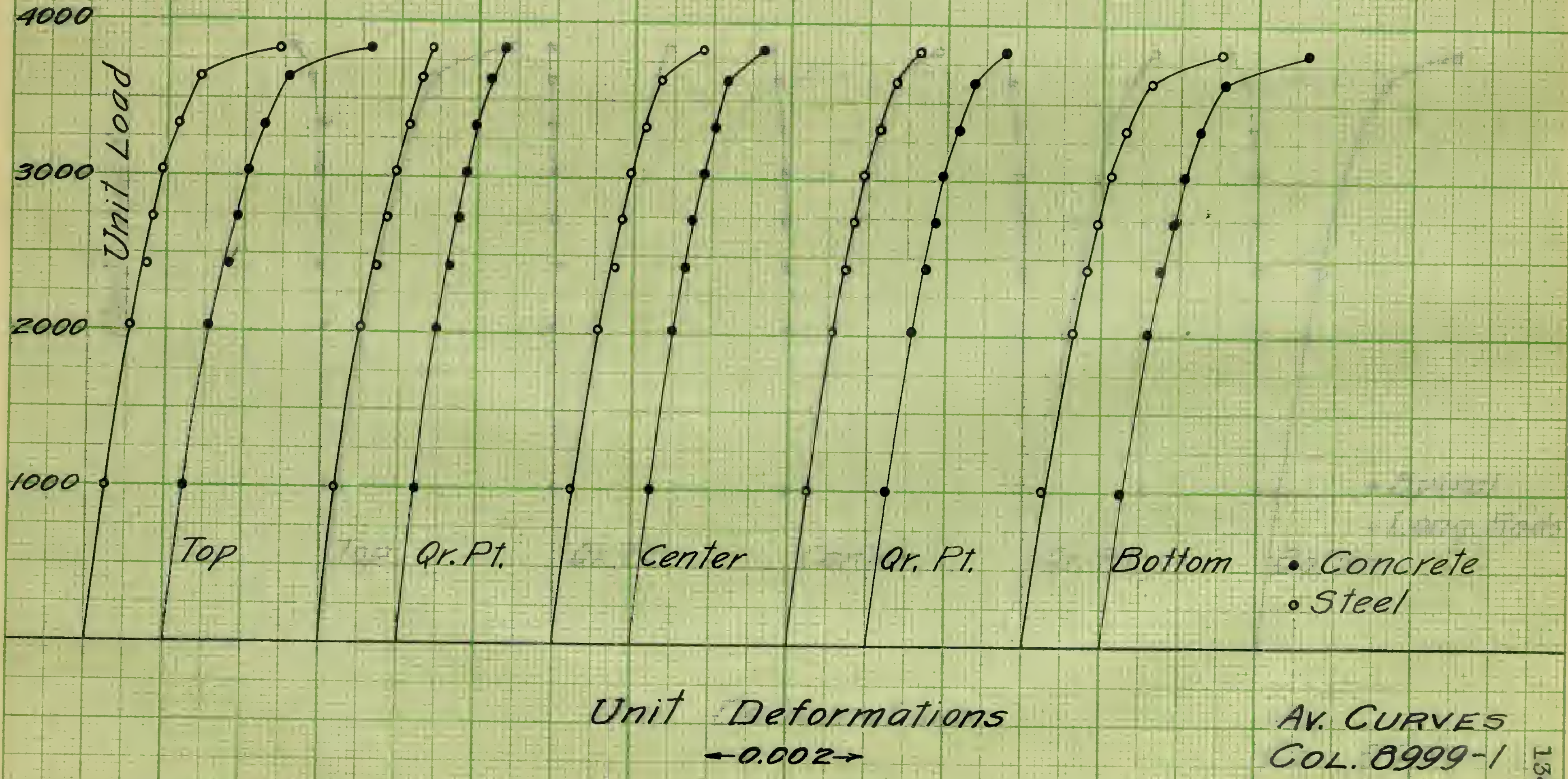

4000
3000
2000
1000
Unit Load
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
• Concrete
∘ Steel
Unit Deformations
← 0.002 →
Av. CURVES
COL. 8998-2


Av. CURVES
COL. 8998-Z
• Spiral
∘ Long. Rods
Top
Qr. Pt.
Center
Qr. Pt.
Bottom
Unit Deformations
←0.002→
Unit Load
1000
2000
3000
4000

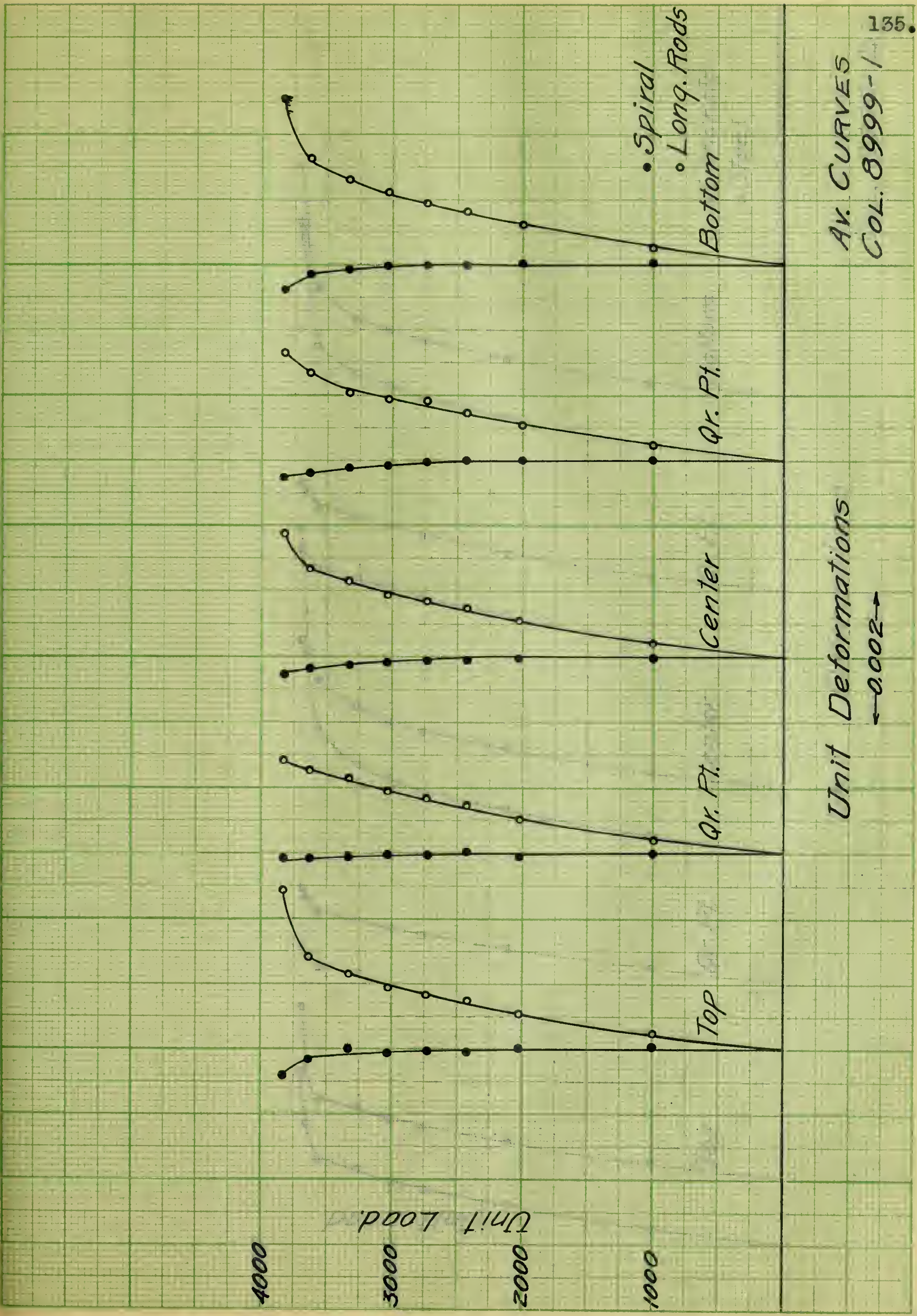

Av. CURVES
COL. 8998-5
• Concrete
∘ Steel
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
←0.0002→
Unit Load
4000
3000
2000
1000

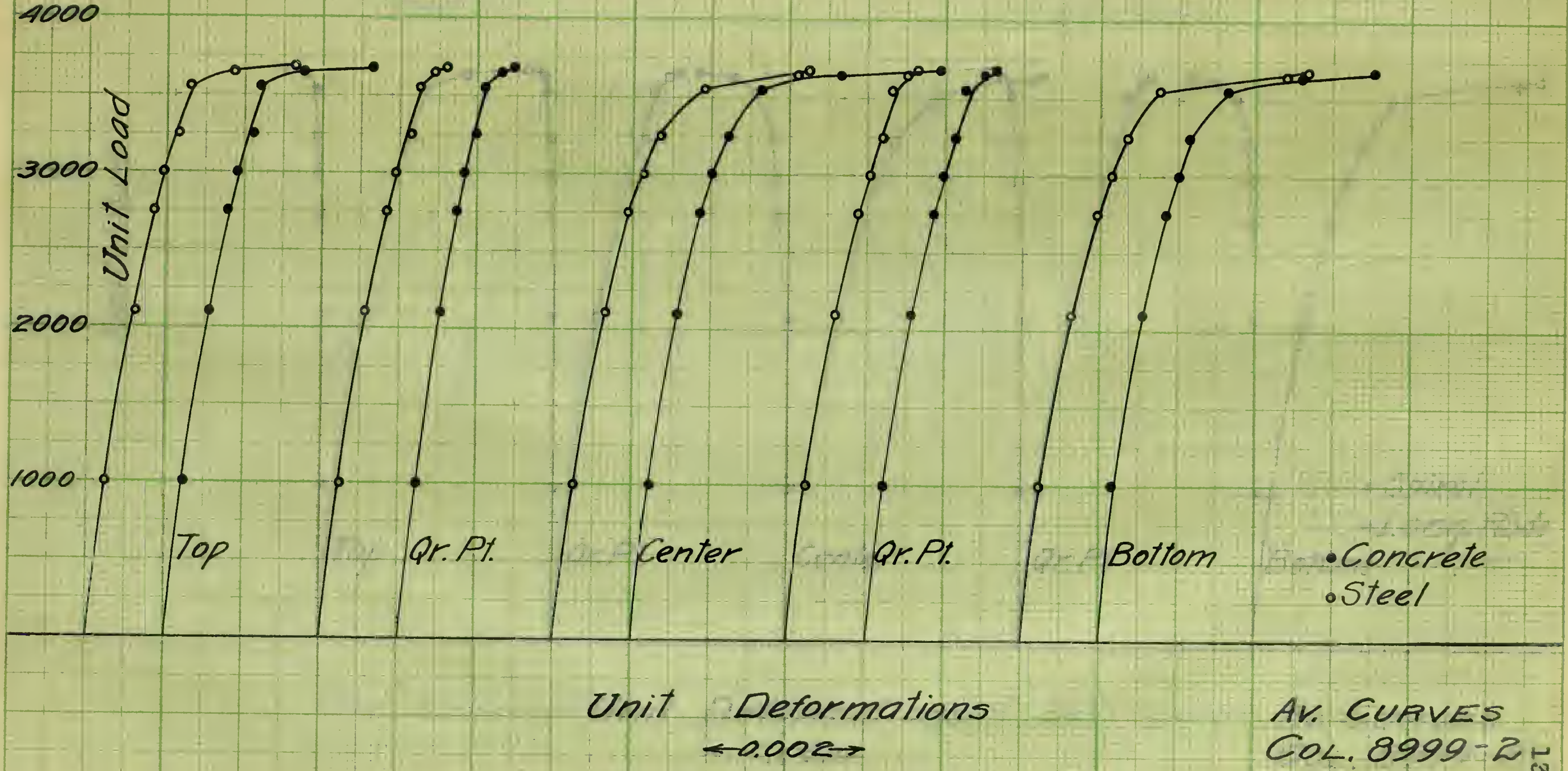


Av. Curves
Col. 8998-3

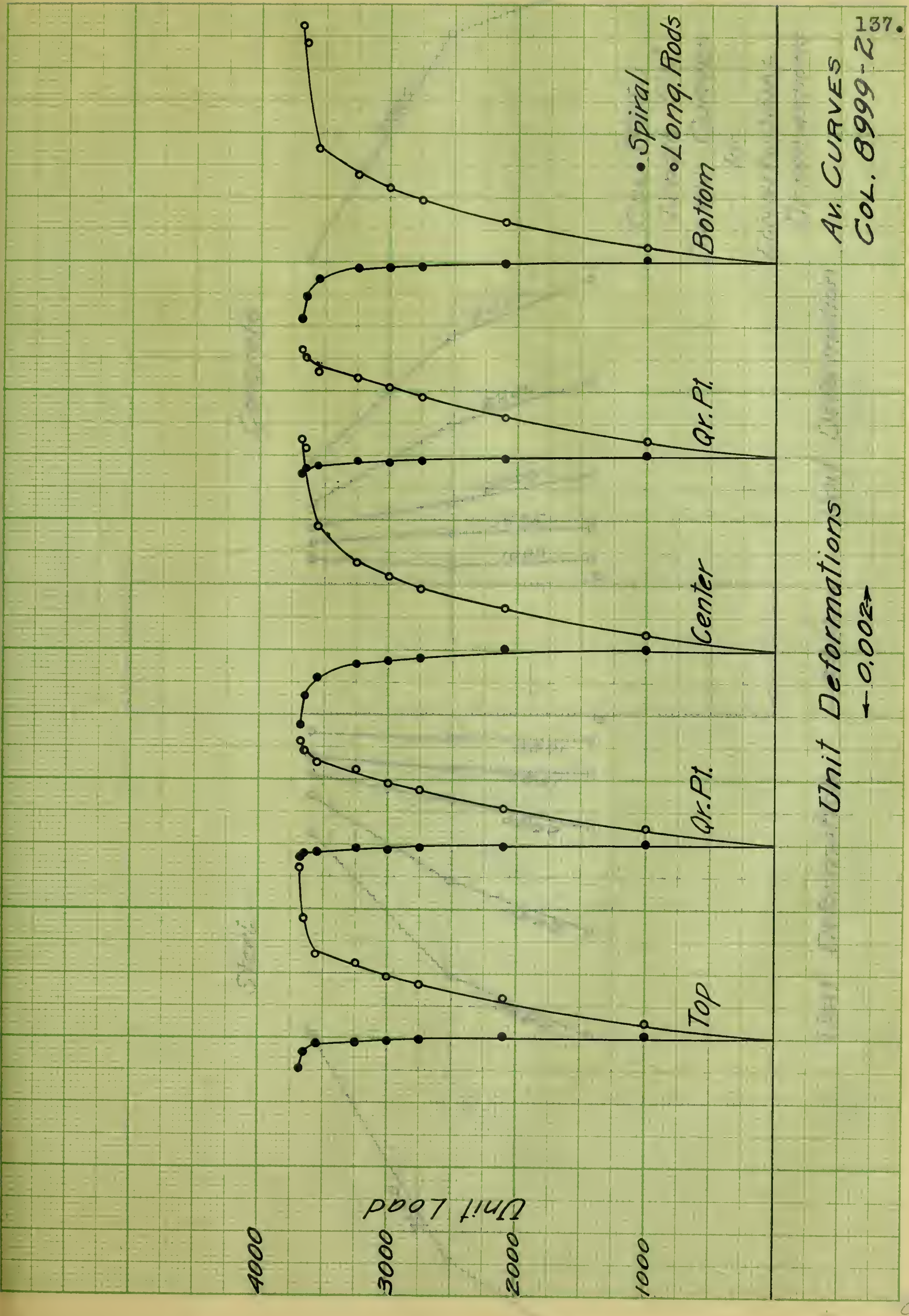


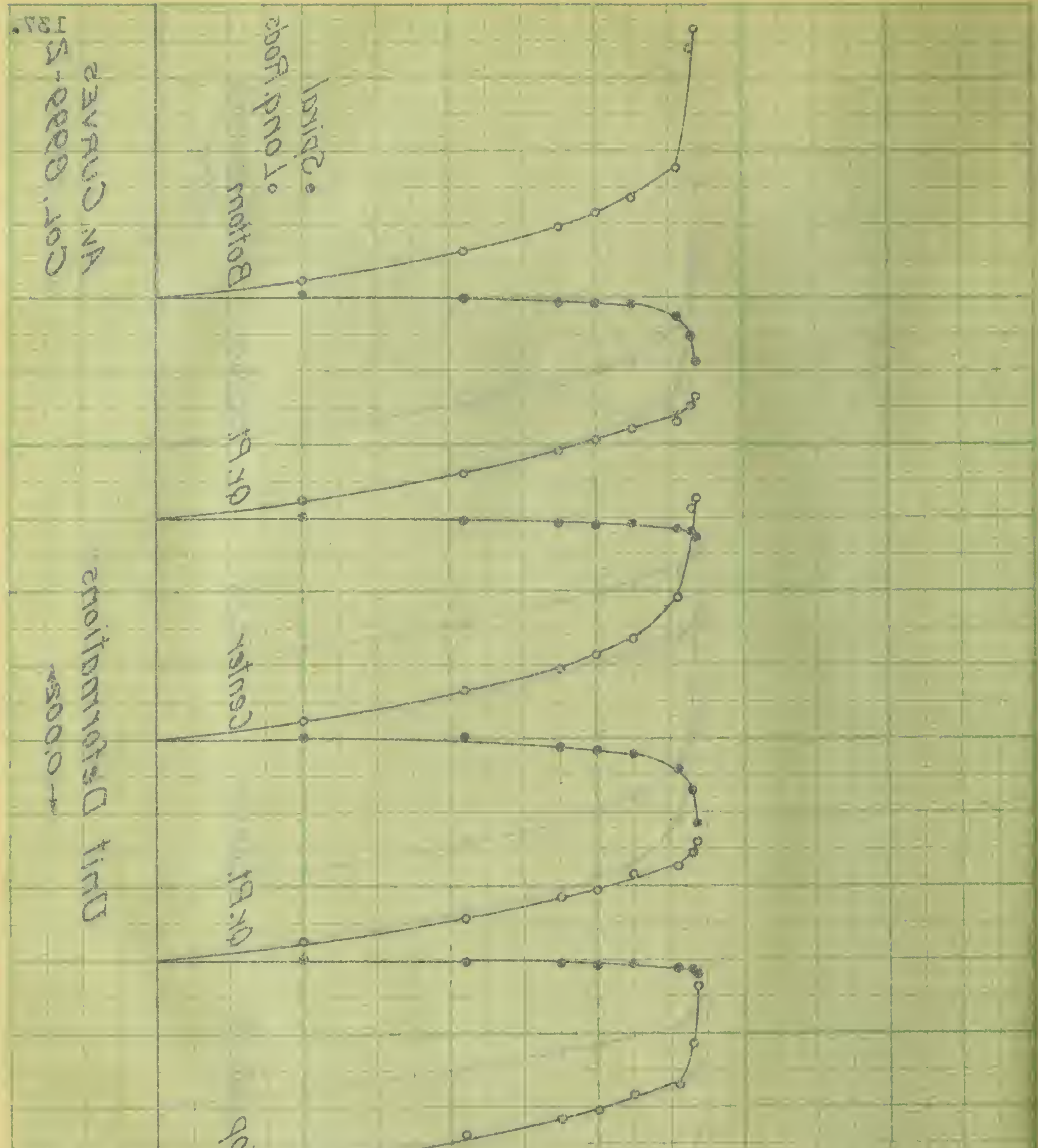
Av. CURVES
COL. 8999-1

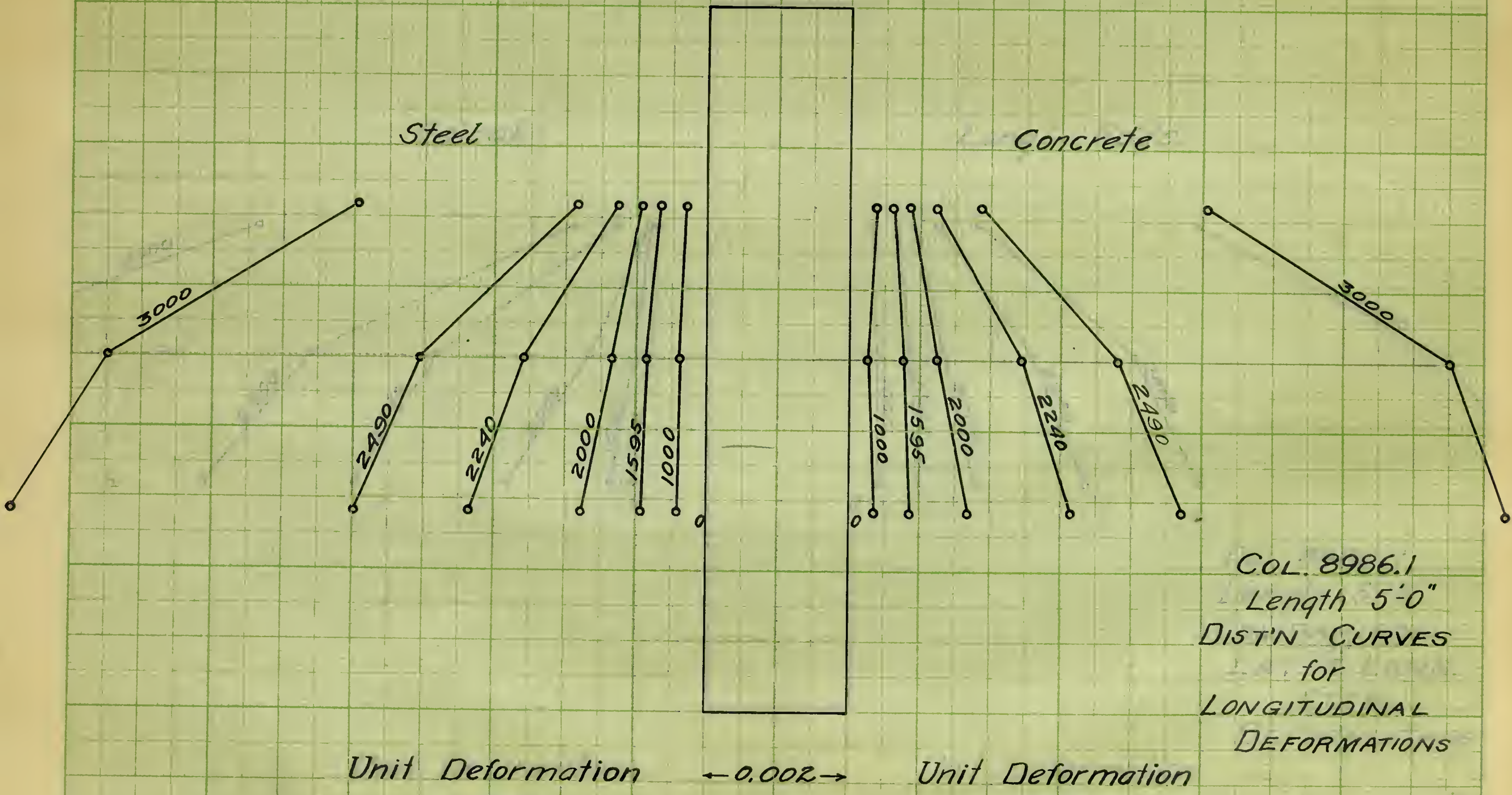

Av. CURVES
COL. 8999-1
• Spiral
∘ Long. Rods
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
0.002
Unit Load
4000
3000
2000
1000



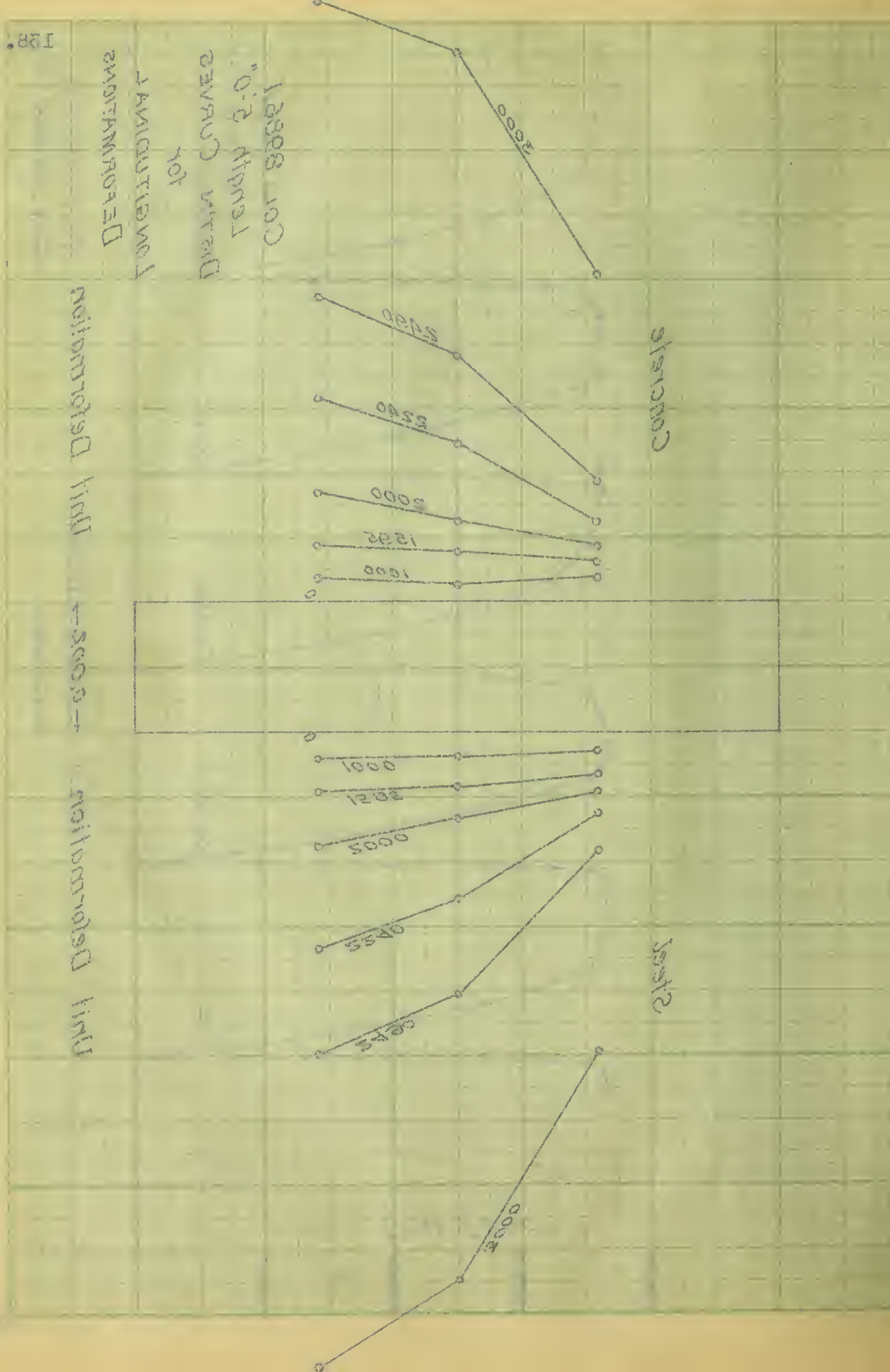
Av. Curves
Col. 8999-2

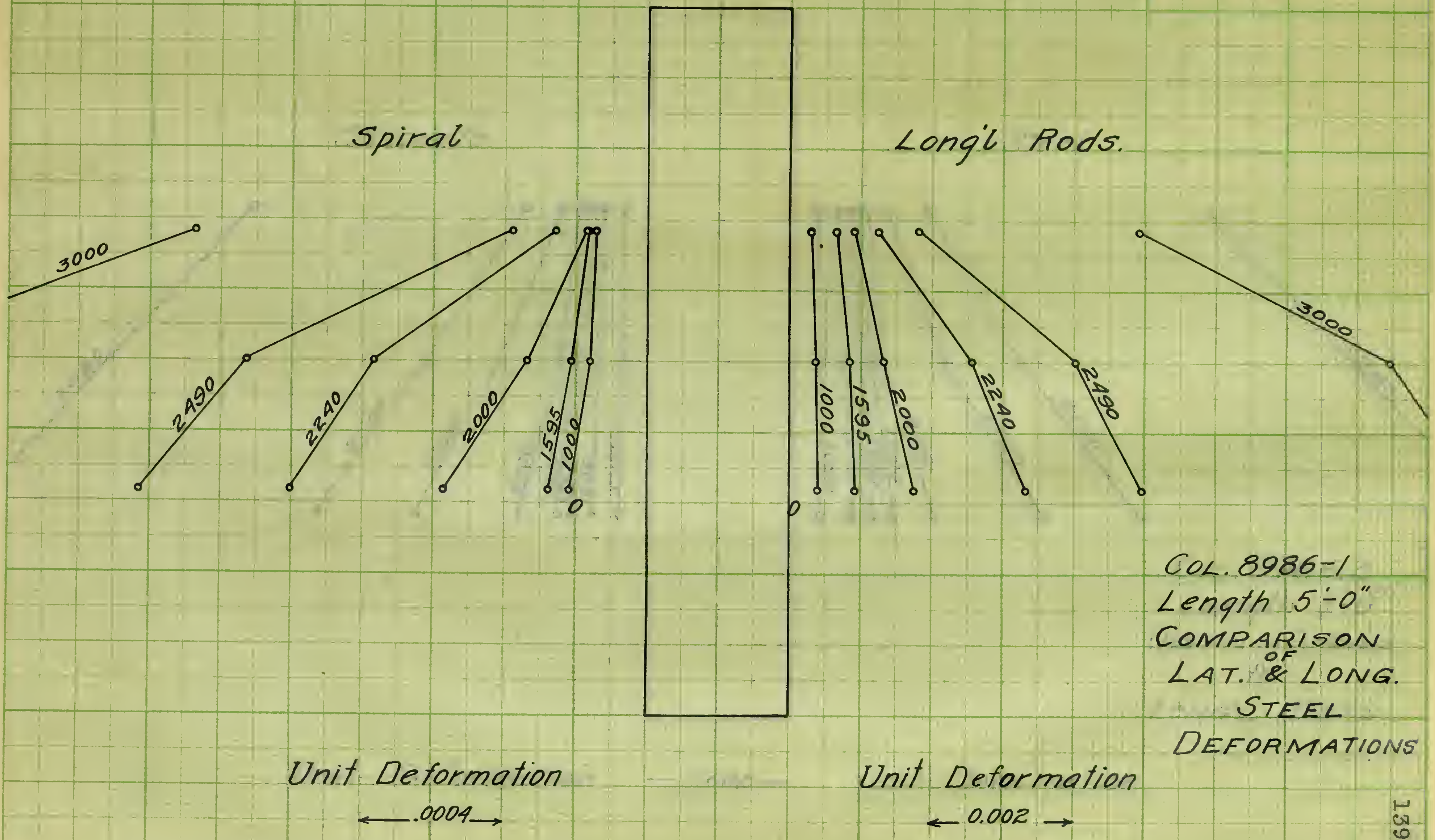

Av. CURVES
COL. 8999-2
• Spiral
∘ Long. Rods
Bottom
Qr. Pt.
Center
Qr. Pt.
Top
Unit Deformations
← 0.002 →
Unit Load
4000
3000
2000
1000


137.
Av. Curves
Col. 6999-Z
Unit Deformations
0.002
Unit Load
1000
2000
3000
4000
Top
Qr.Pt.
Center
Qr.Pt.
Bottom
• Spiral
○ Long. Rods

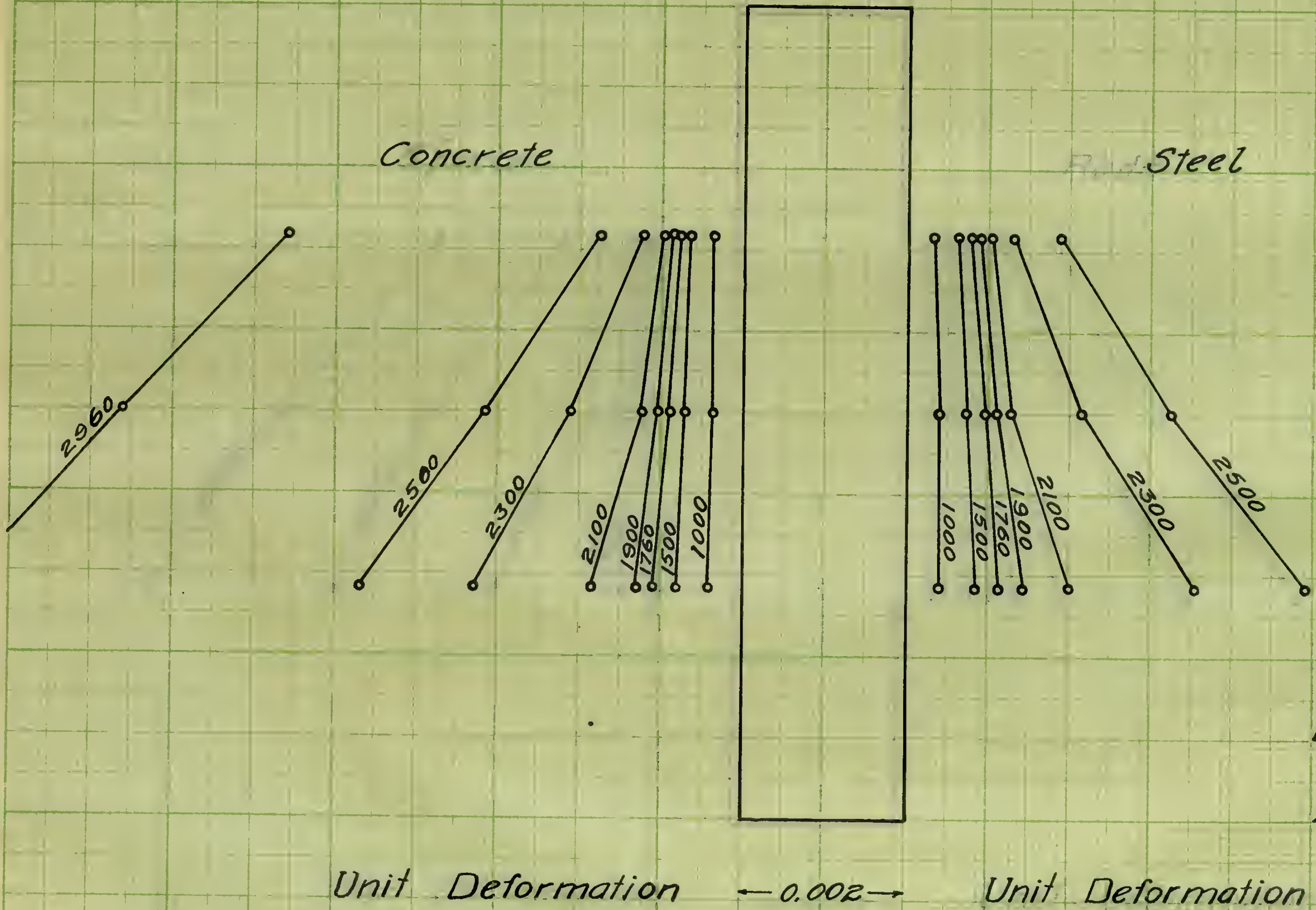


COL. 8986.1
Length 5'-0"
DIST'N CURVES
for
LONGITUDINAL
DEFORMATIONS

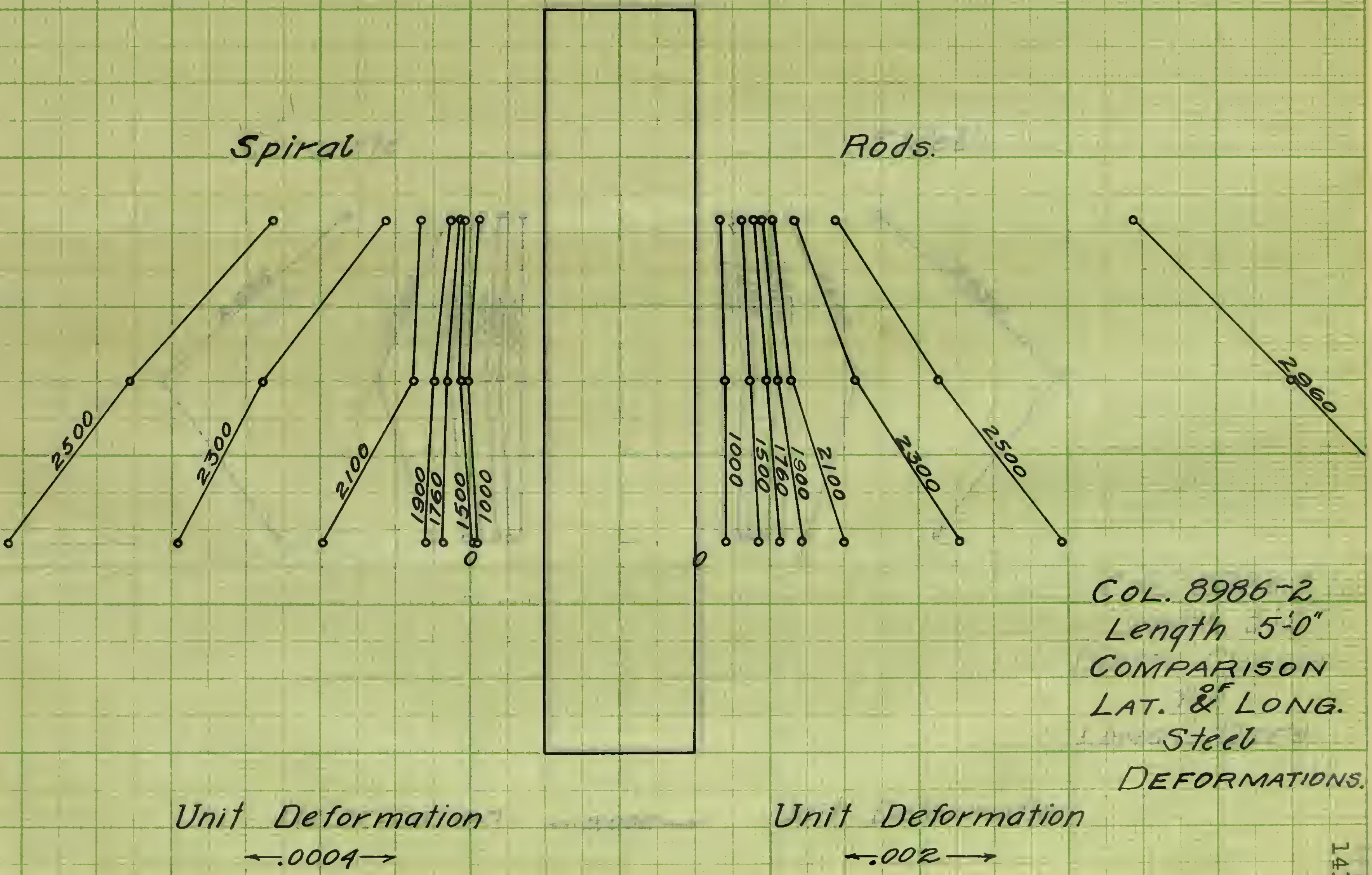

Col. 8986.1
Length 5'-0"
Distn Curves
for
Longitudinal
Deformations
Unit Deformation ←.002→ Unit Deformation
Concrete
Steel
1000
1595
2000
2240
2490
3000
1000
1595
2000
2240
2490
3000



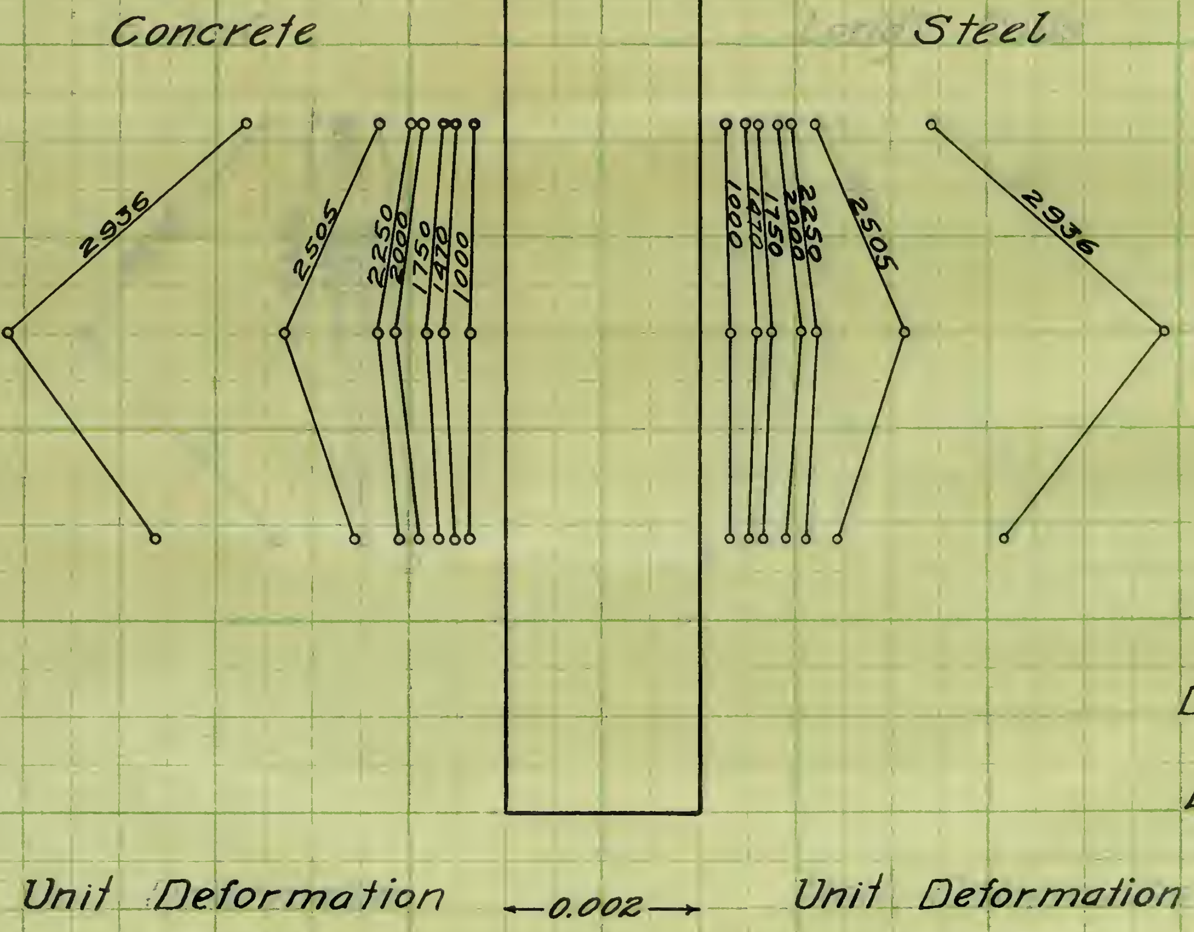
Col. 8986-1
Length 5'-0"
Comparison of Lat. & Long. Steel Deformations



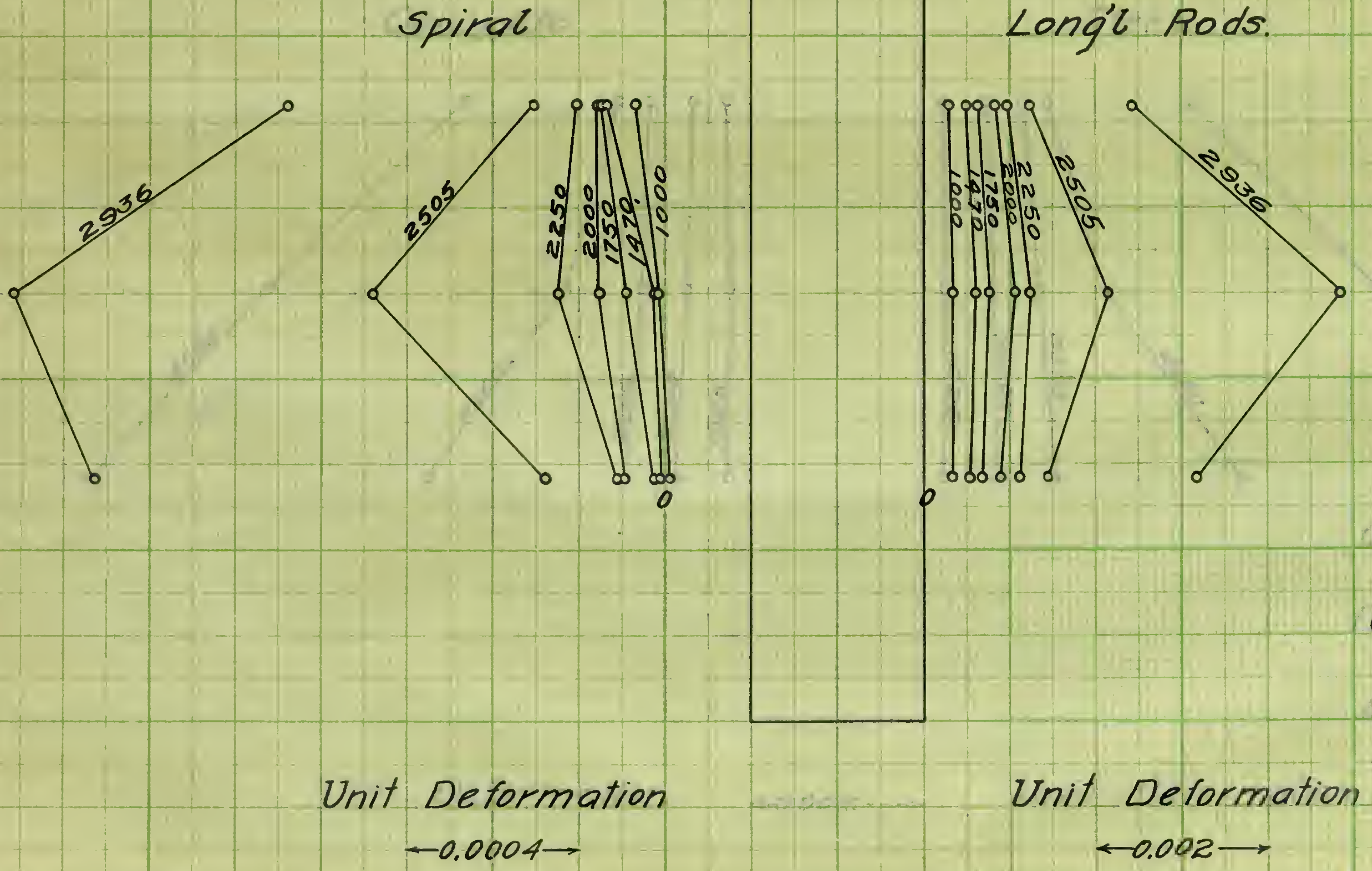
COL. 8986.2
Length 5'-0"
DIST'N CURVES
for
LONG'L DEF'S



COL. 8986-2
Length 5'-0"
COMPARISON
of
LAT. & LONG.
Steel
DEFORMATIONS.

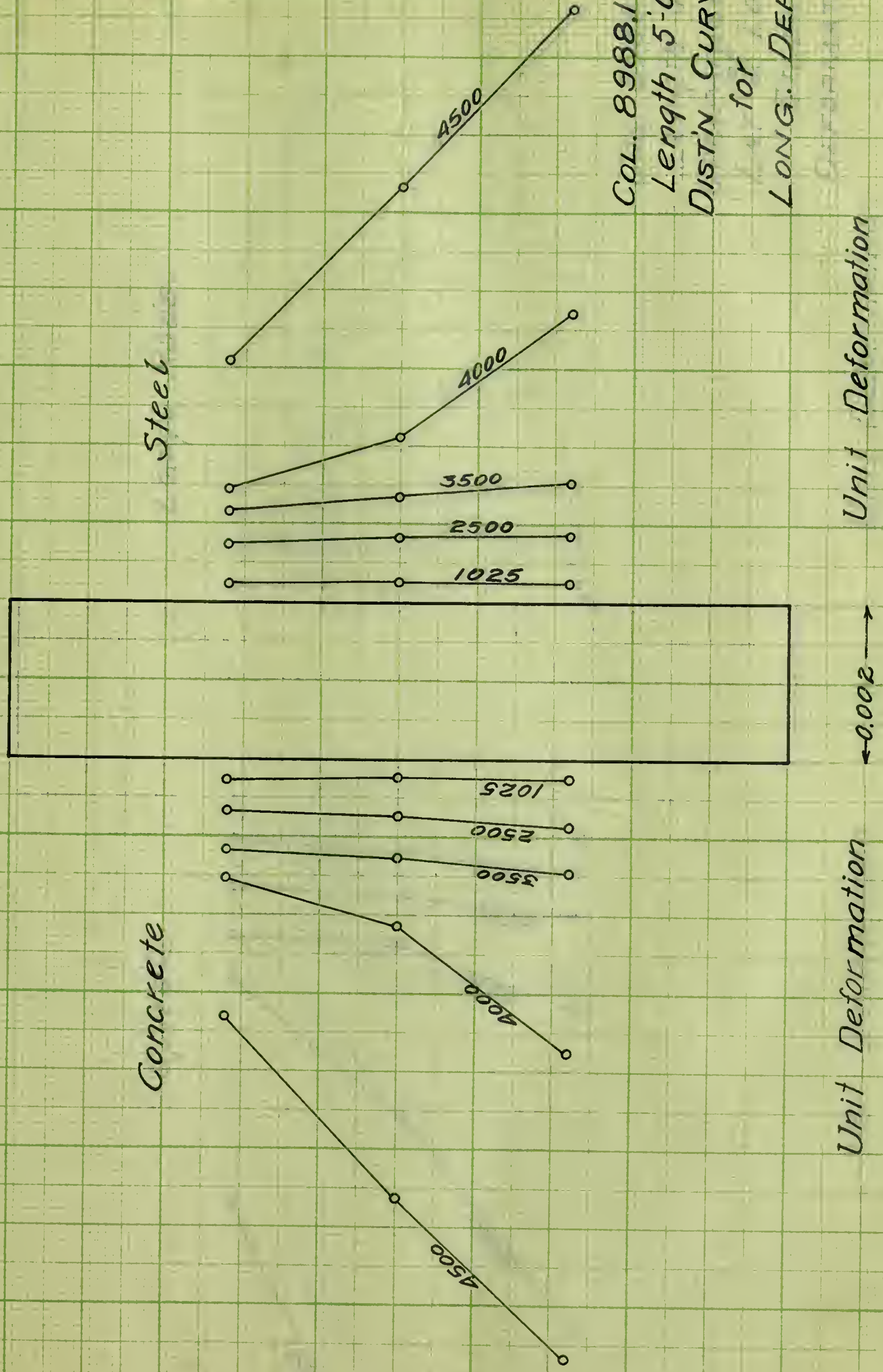


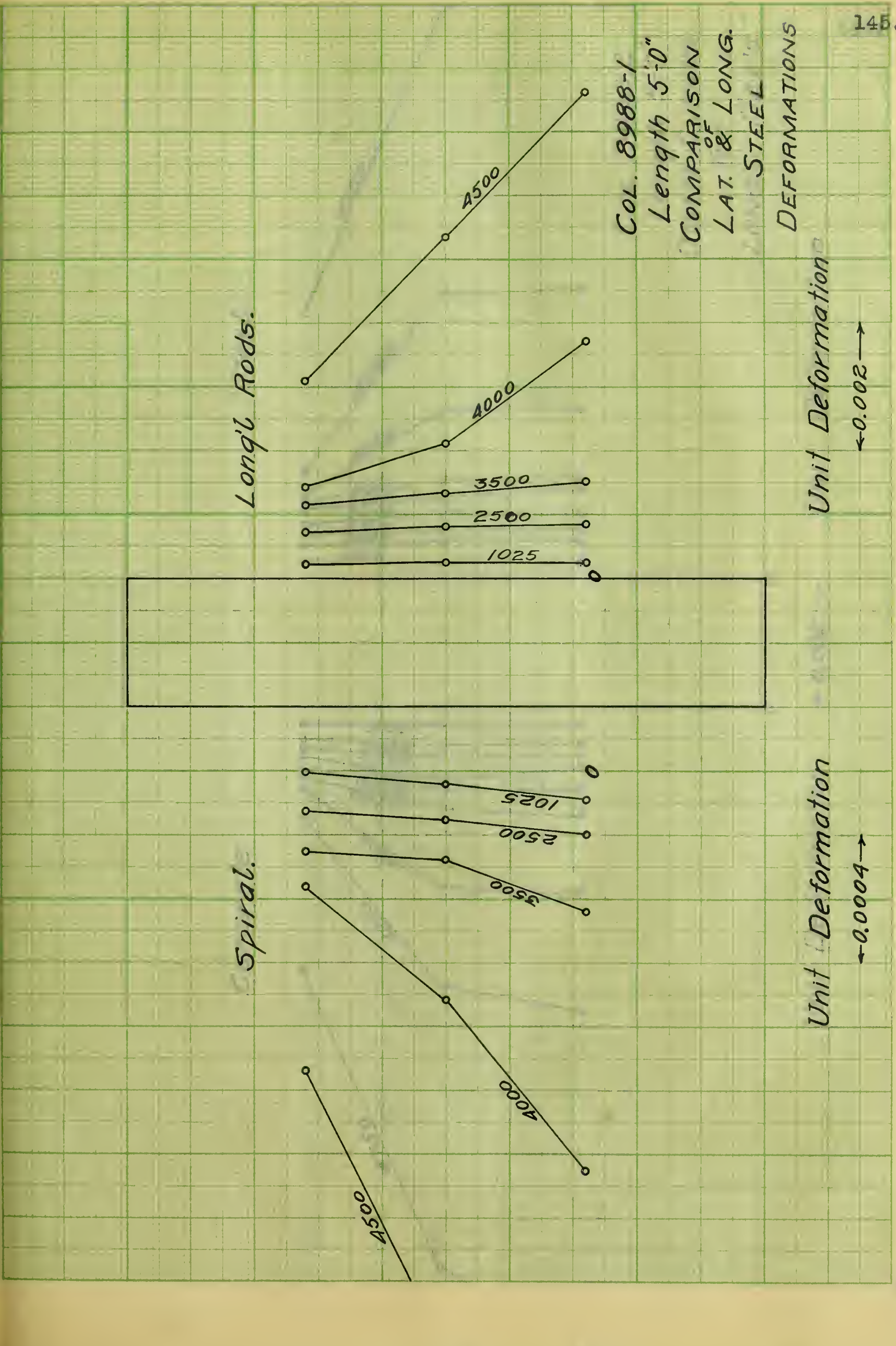
Col. 8986.3
Length 5'-0"
Dist'n Curves
for
Long'l Def's.

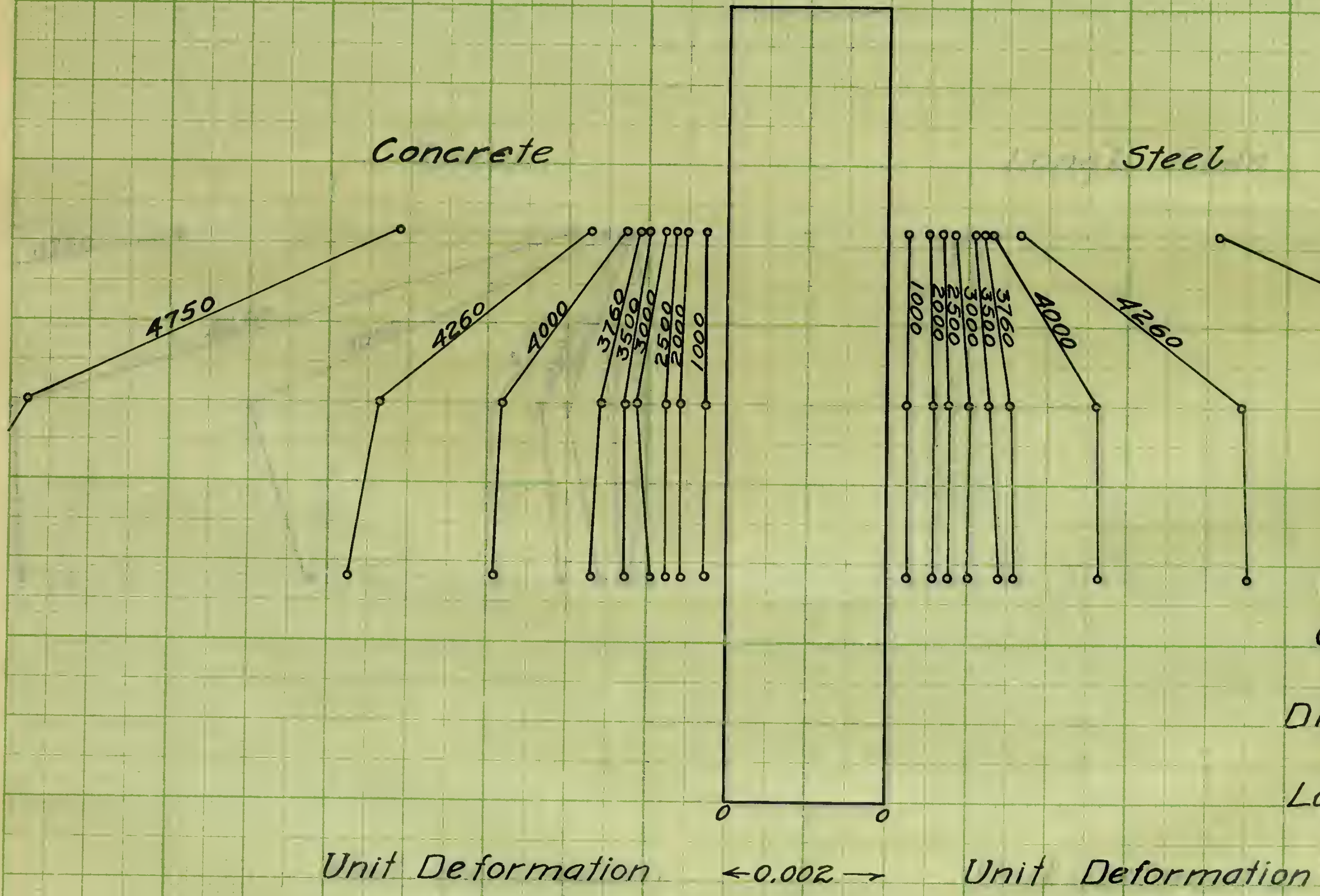


Col. 8986-3
Length 5'-0"
Comparison
of
Lat. & Long.
Steel
Deformations.

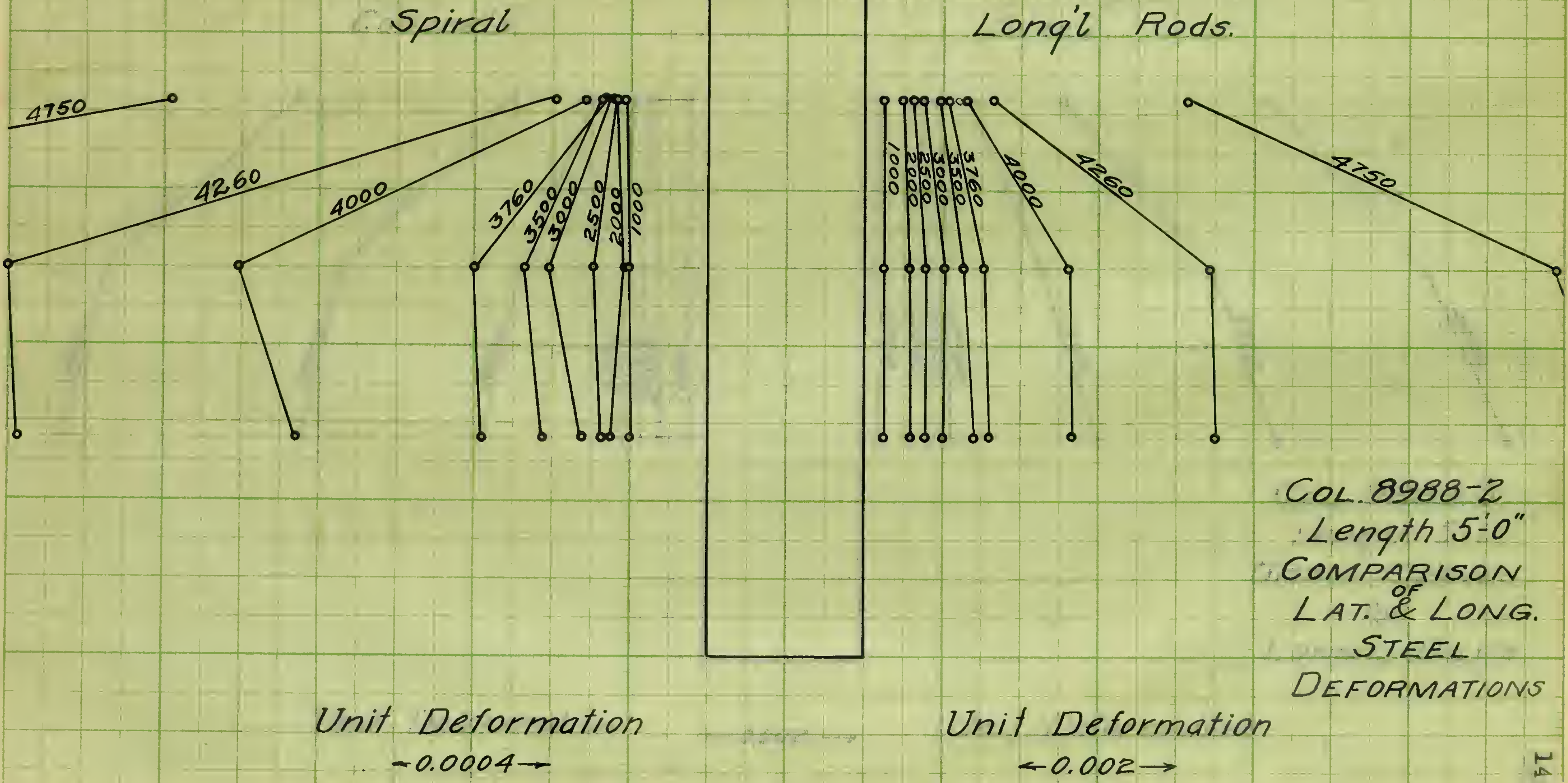
Col. 8988.1
Length 5'-0"
Dist'n Curves
for
Long. Def's.



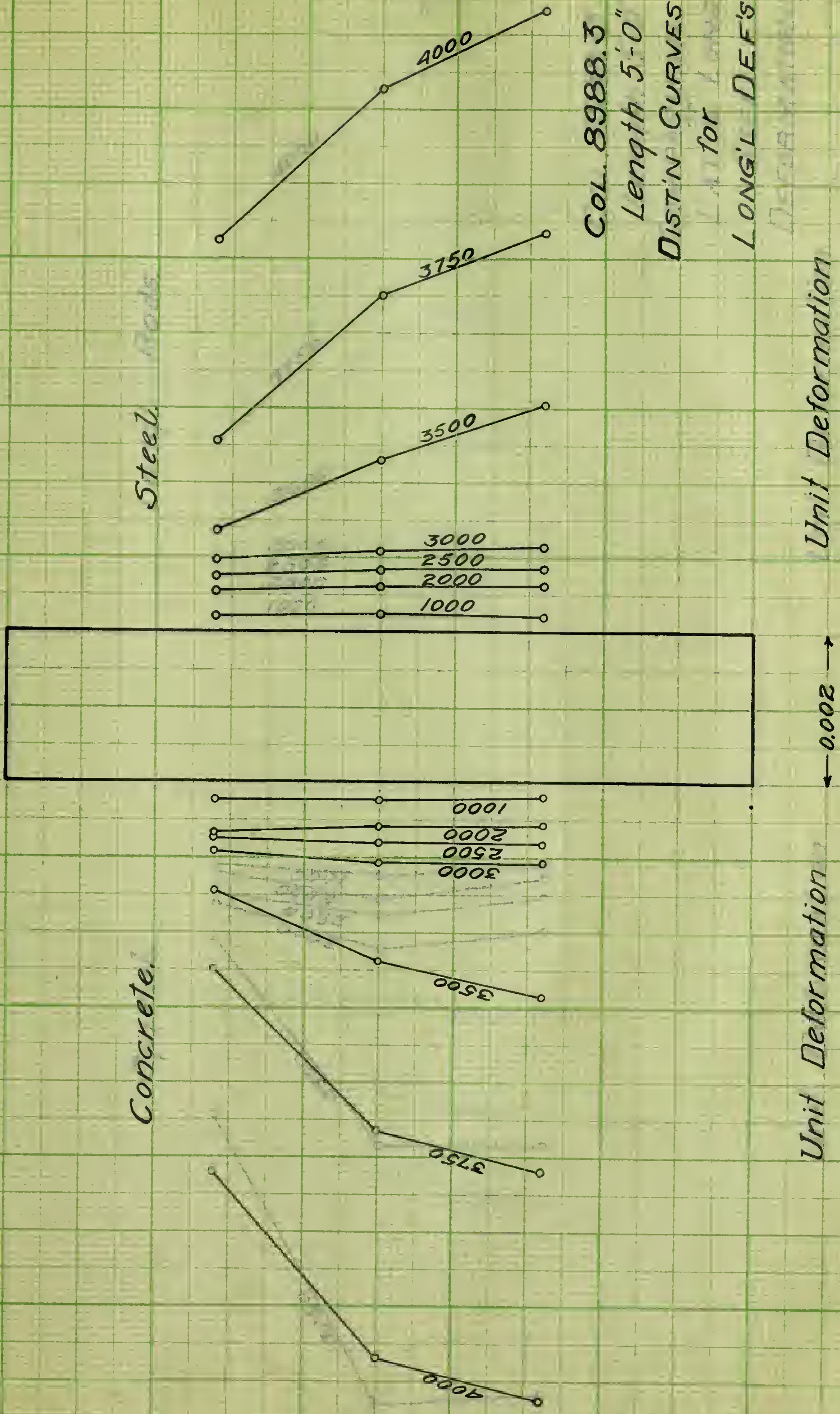

Col. 8988-1
Length 5'-0"
Comparison of Lat. & Long. Steel Deformations
Long'l Rods.
Spiral.
4500
4000
3500
2500
1025
0
Unit Deformation
←0.002→
Unit Deformation
←0.0004→



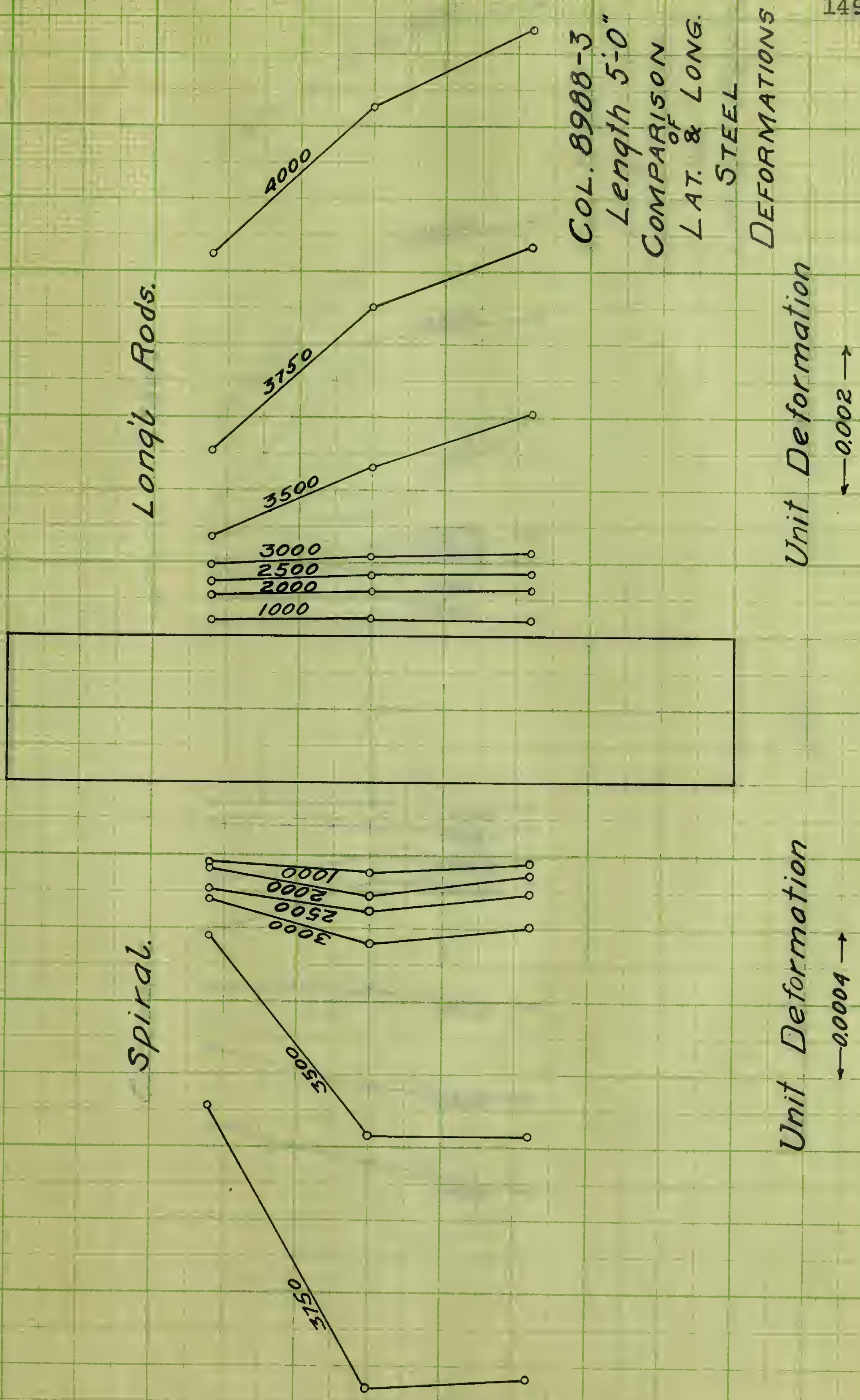
COL. 8988.2
Length 5'-0"
DIST'N CURVES
for
LONG'L DEF'S.

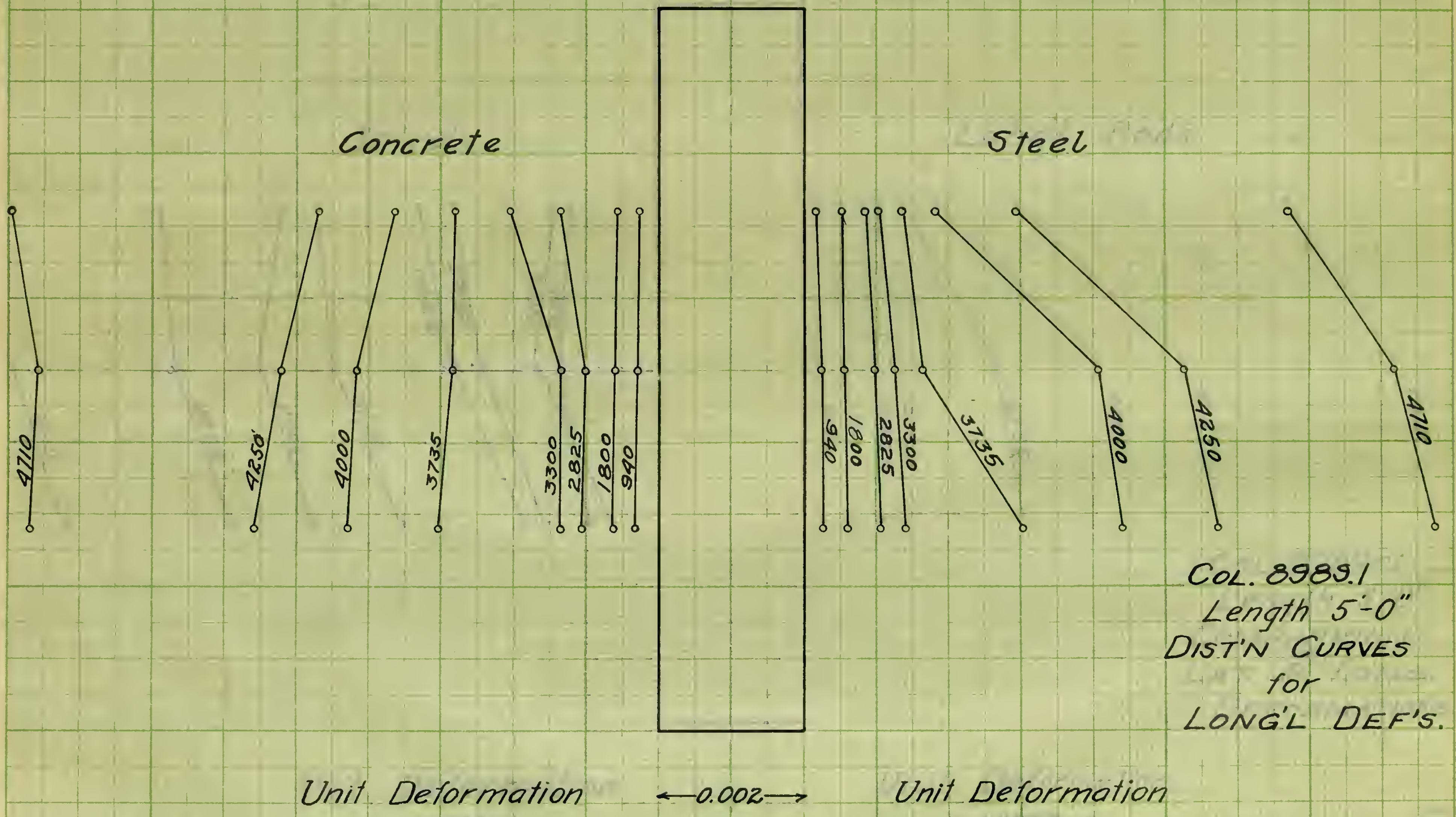


Col. 8988-2
Length 5'-0"
Comparison of
Lat. & Long.
Steel
Deformations

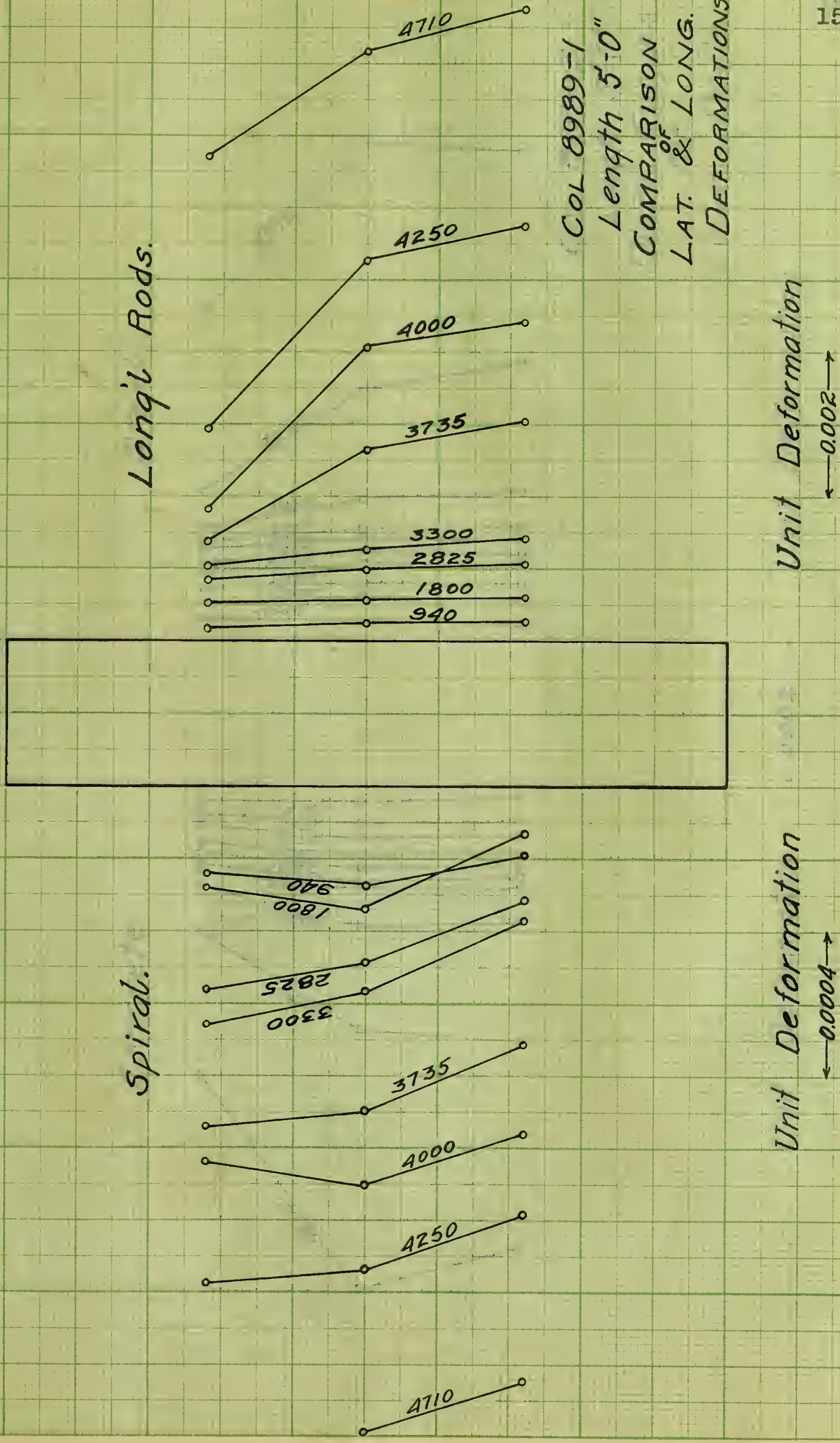


Col. 8988.3
Length 5'-0"
Dist'n Curves
for
Long'l Def's

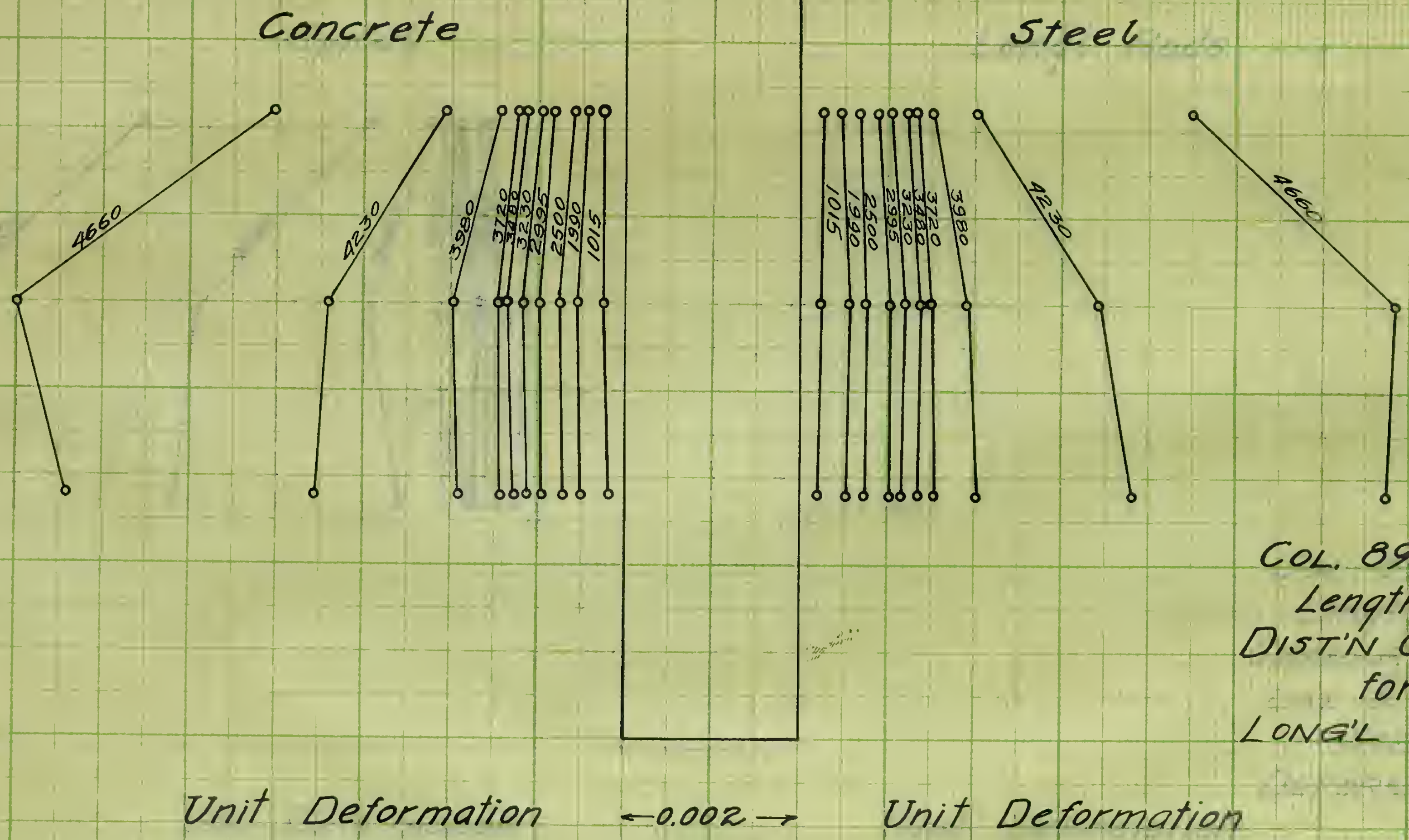

Col. 8988-3
Length 5'-0"
Comparison of Lat. & Long. Steel Deformations
Long'l. Rods.
4000
3750
3500
3000
2500
2000
1000
Unit Deformation
← 0.002 →
Spiral.
1000
2000
2500
3000
3500
3750
Unit Deformation
← 0.0004 →

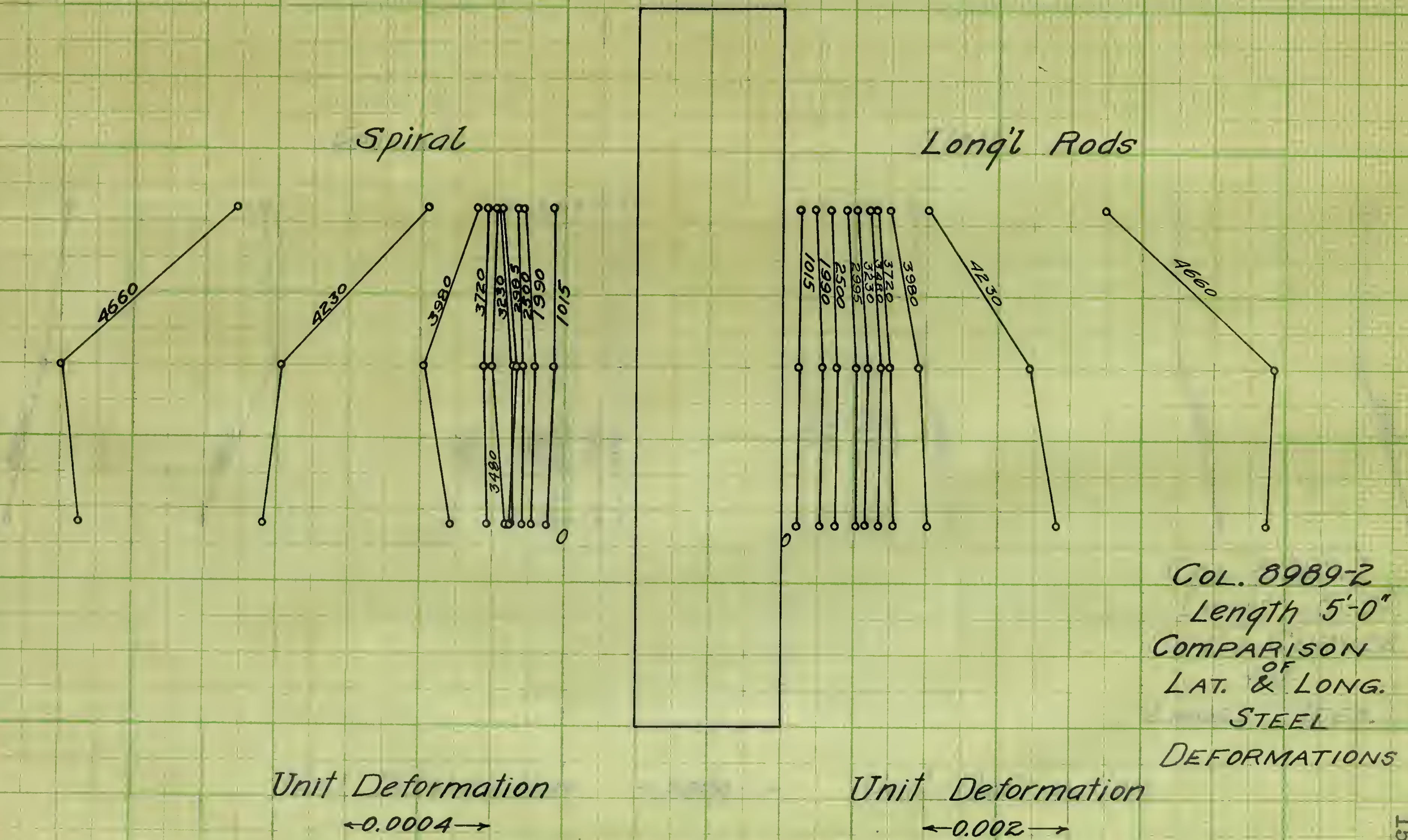


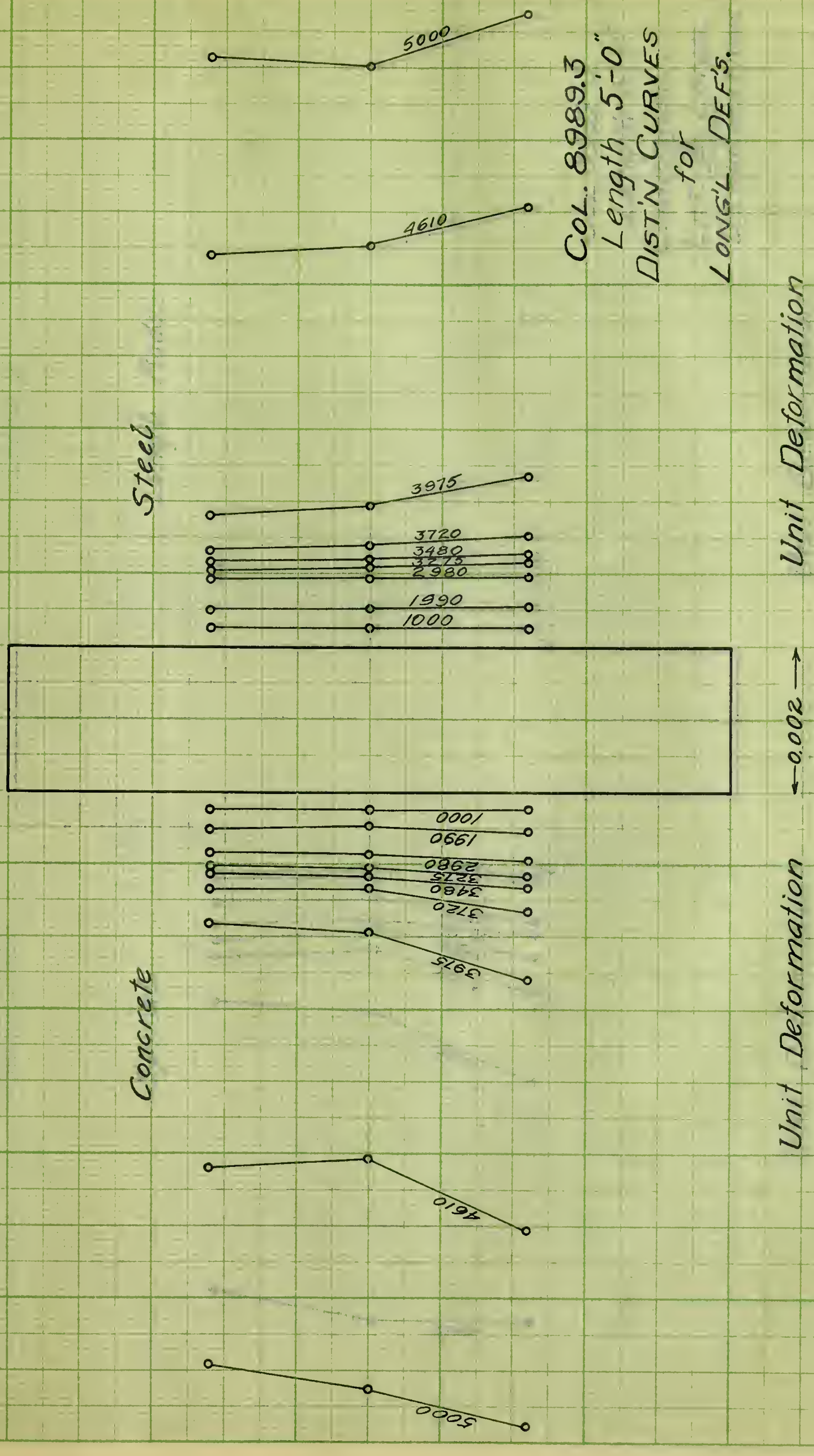
COL. 8989.1
Length 5'-0"
DIST'N CURVES
for
LONG'L DEF'S.

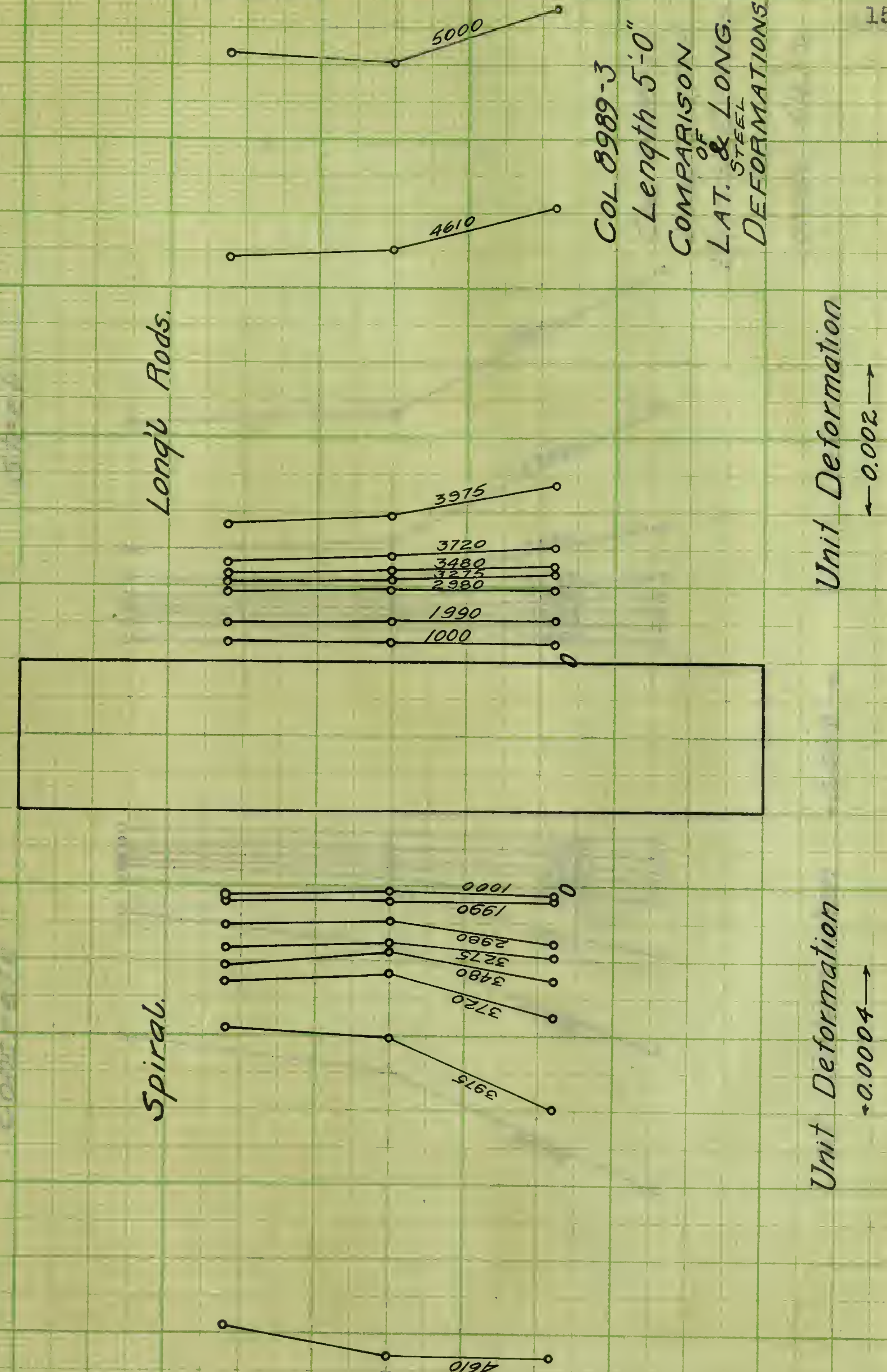

Col 8989-1
Length 5'-0"
Comparison of Lat. & Long. Deformations
Long'l Rods.
4710
4250
4000
3735
3300
2825
1800
940
Unit Deformation
0.002
Spiral.
940
1800
2825
3300
3735
4000
4250
4710
Unit Deformation
0.0004

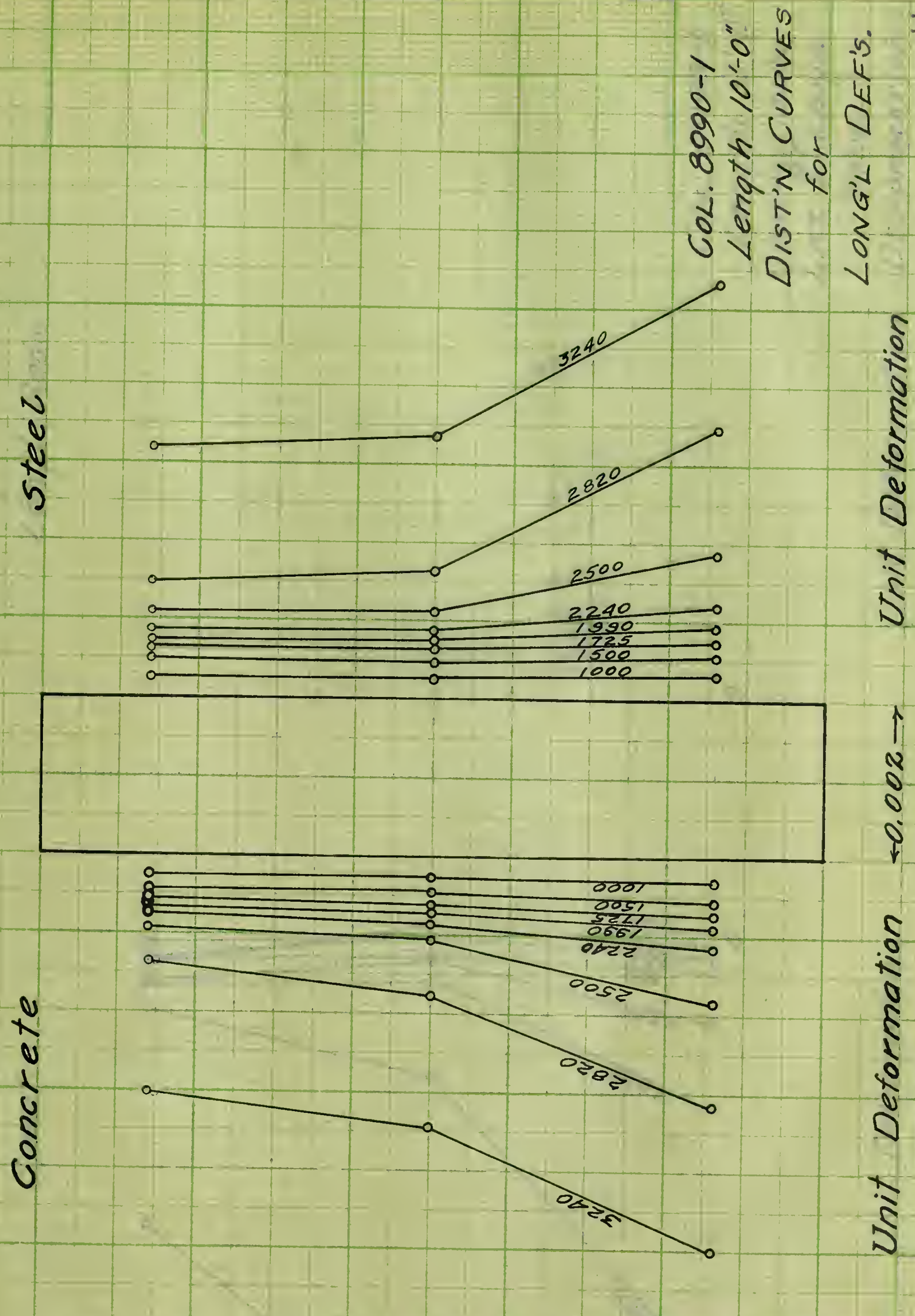
Col. 8989-2
Length 5'-0"
Dist'n Curves
for
Long'l Def's.



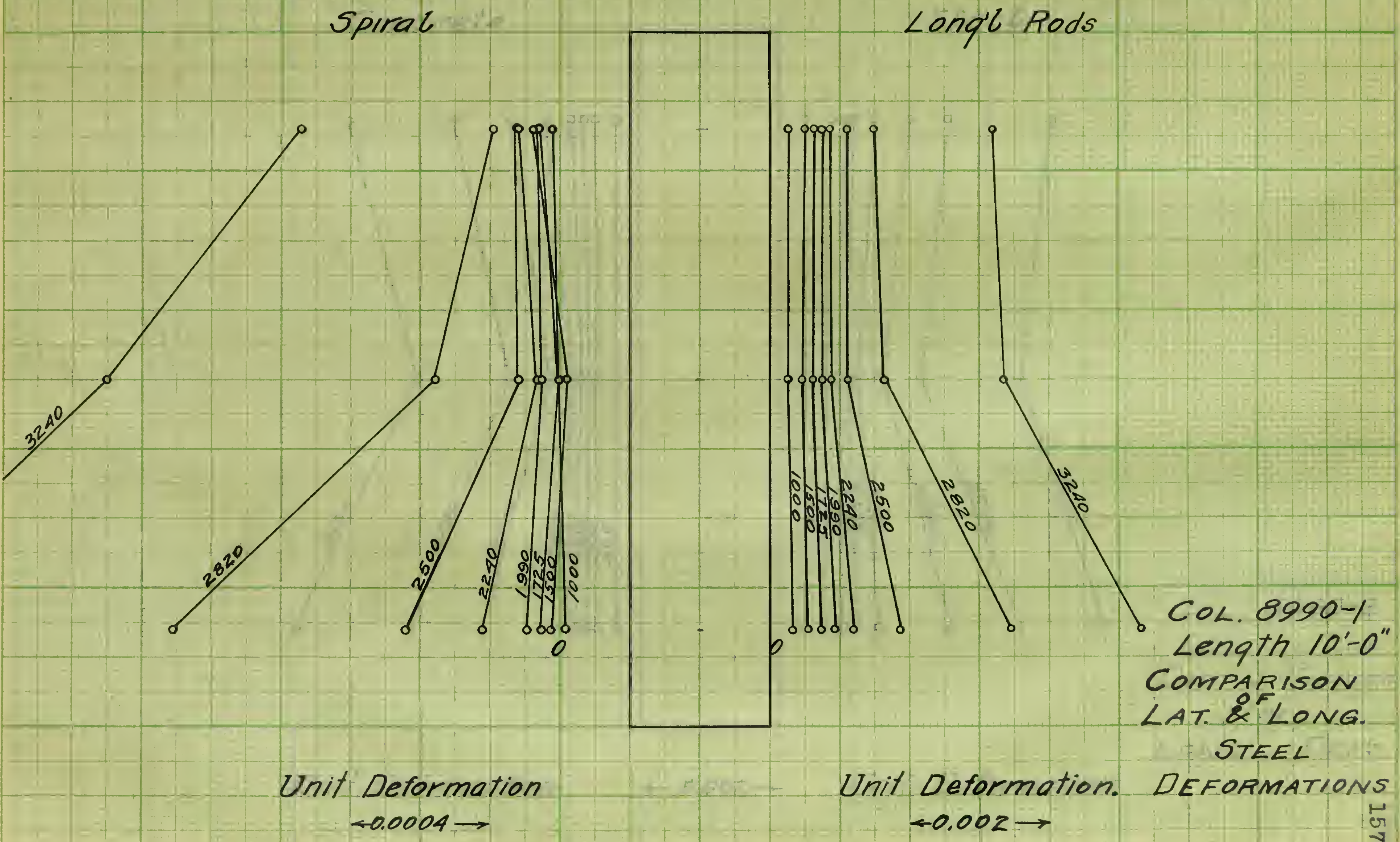

Spiral
Long'l Rods
4660
4230
3980
3720
3480
3230
2995
2500
1990
1015
0
4660
4230
3980
3720
3480
3230
2995
2500
1990
1015
0
Col. 8989-Z
Length 5'-0"
Comparison
of
Lat. & Long.
Steel
Deformations
Unit Deformation
←0.0004→
Unit Deformation
←0.002→


Col. 8989.3
Length 5'-0"
Dist'n Curves
for
Long'l Def's.
Steel
Concrete
Unit Deformation
Unit Deformation
0.002
5000
4610
3975
3720
3480
3275
2980
1990
1000
1000
1990
2980
3275
3480
3720
3975
4610
5000

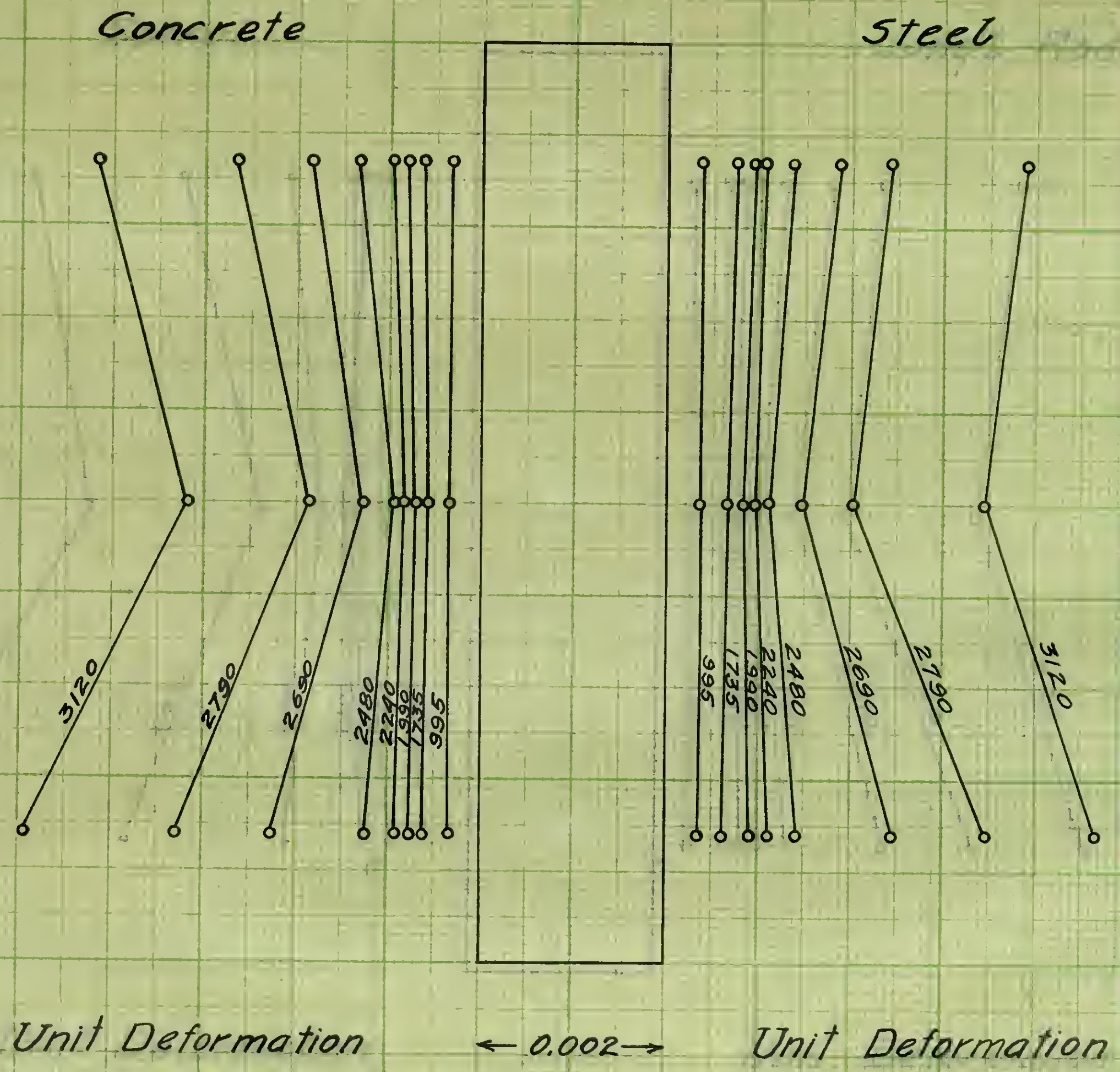

Col 8989-3
Length 5'-0"
Comparison of Lat. & Long. Steel Deformations
Long'l Rods.
5000
4610
3975
3720
3480
3275
2980
1990
1000
0
Unit Deformation
←0.002→
Spiral.
0
1000
1990
2980
3275
3480
3720
3975
4610
Unit Deformation
←0.0004→



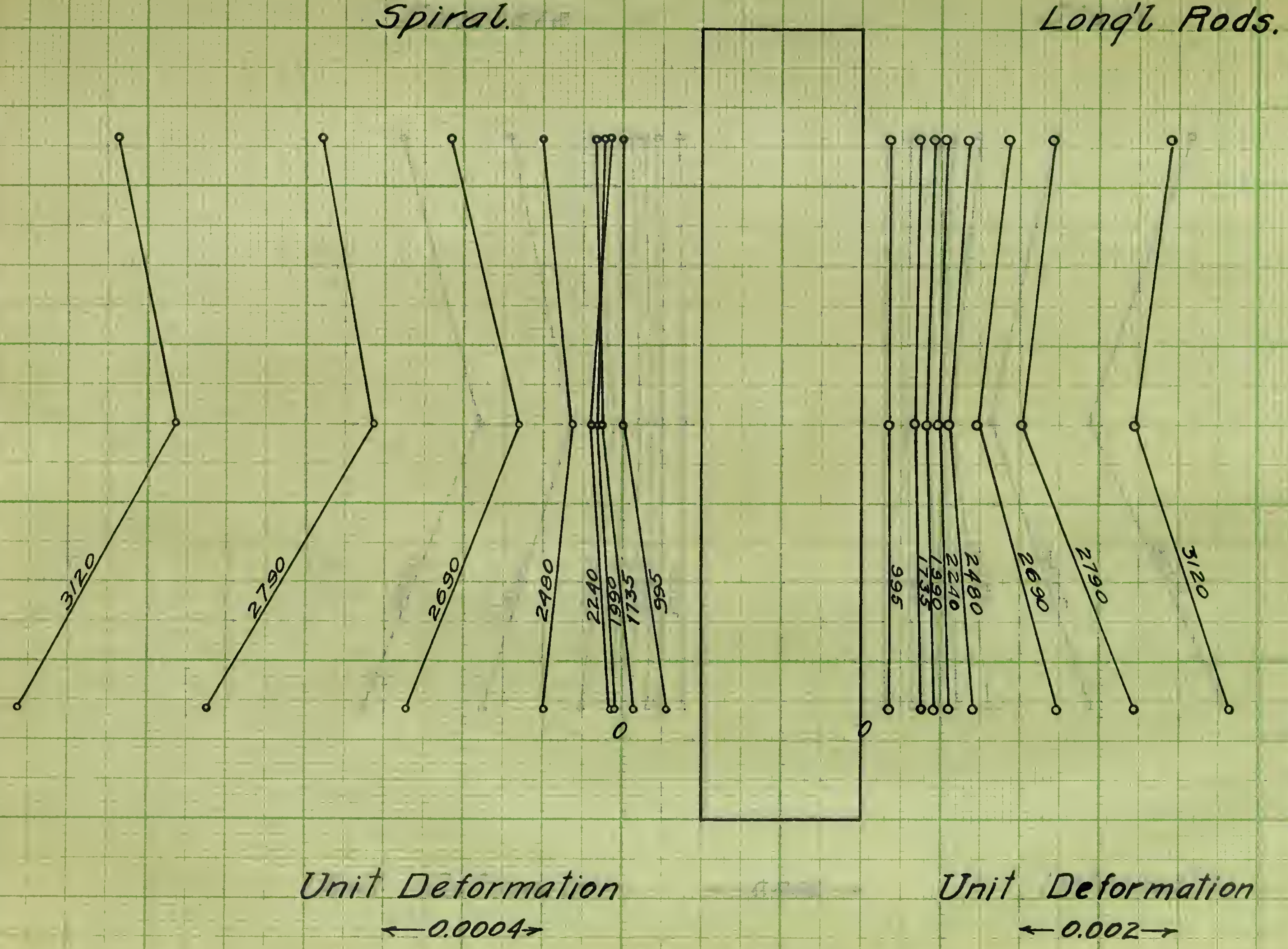
Col. 8990-1
Length 10'-0"
Dist'n Curves
for
Long'l Def's.



Col. 8990-1
Length 10'-0"
Comparison
of
Lat. & Long.
Steel
Deformations

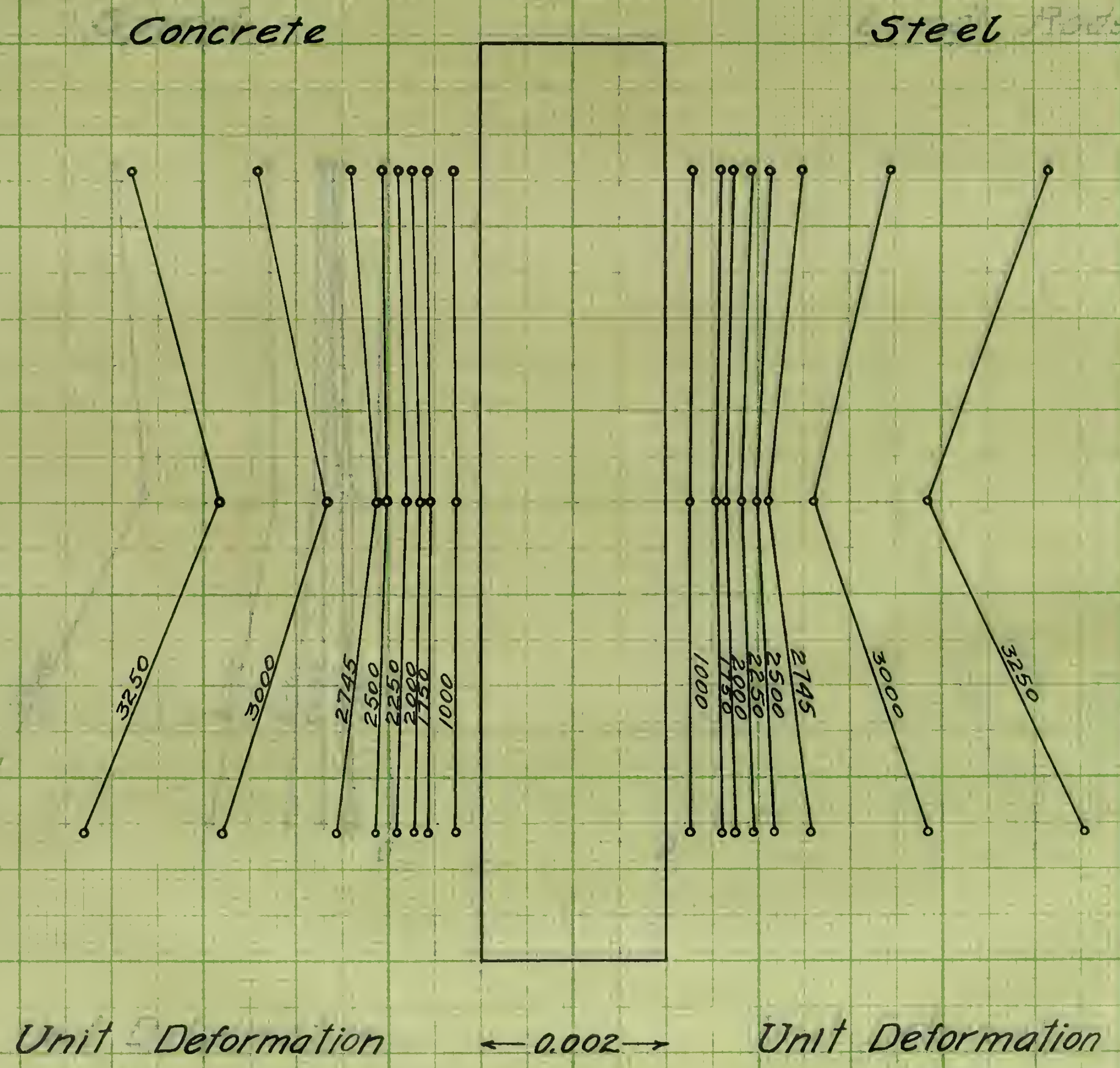


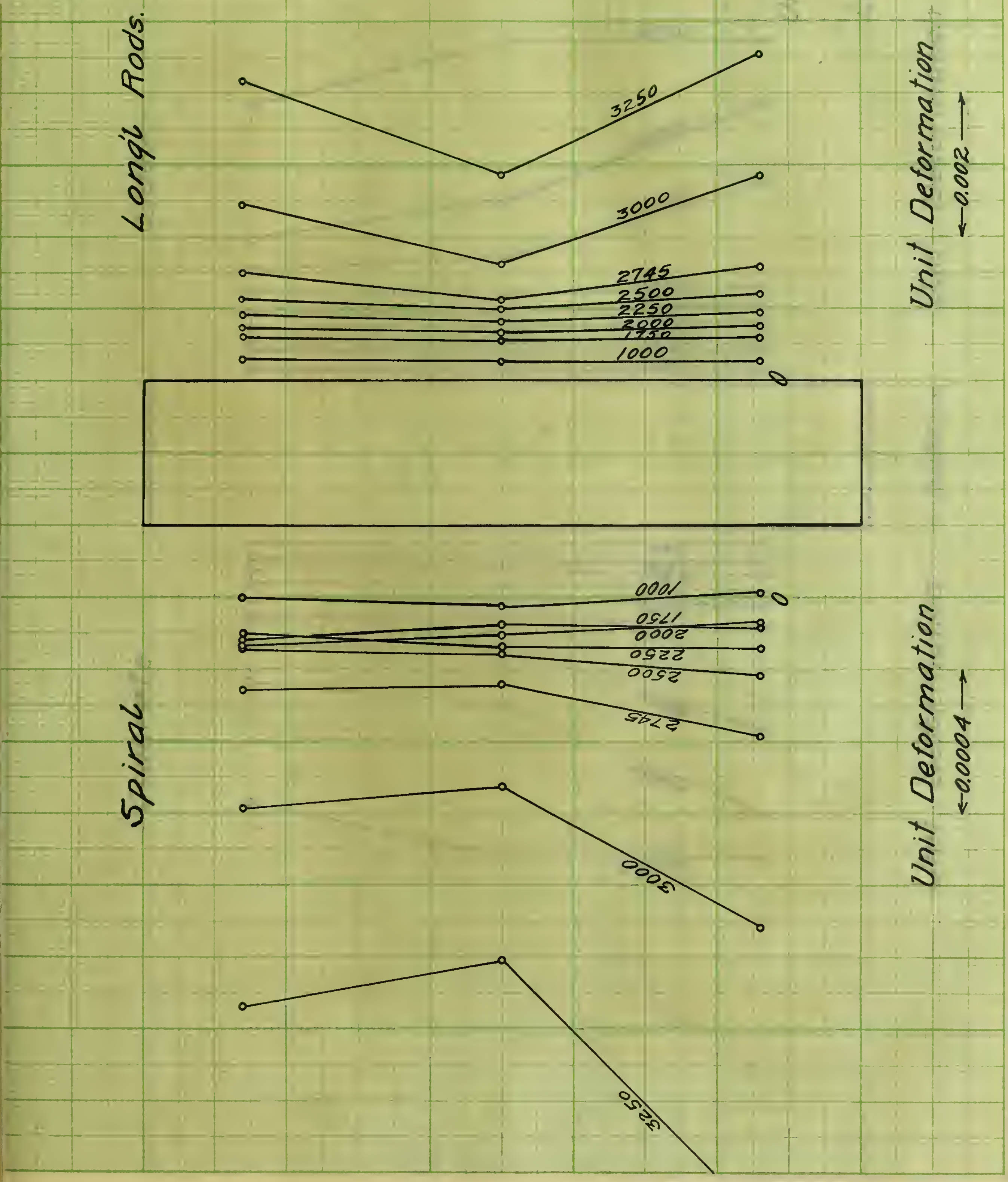
COL. 8990-2
Length 10'-0"
DIST'N CURVES
for
LONG'L DEF'S.



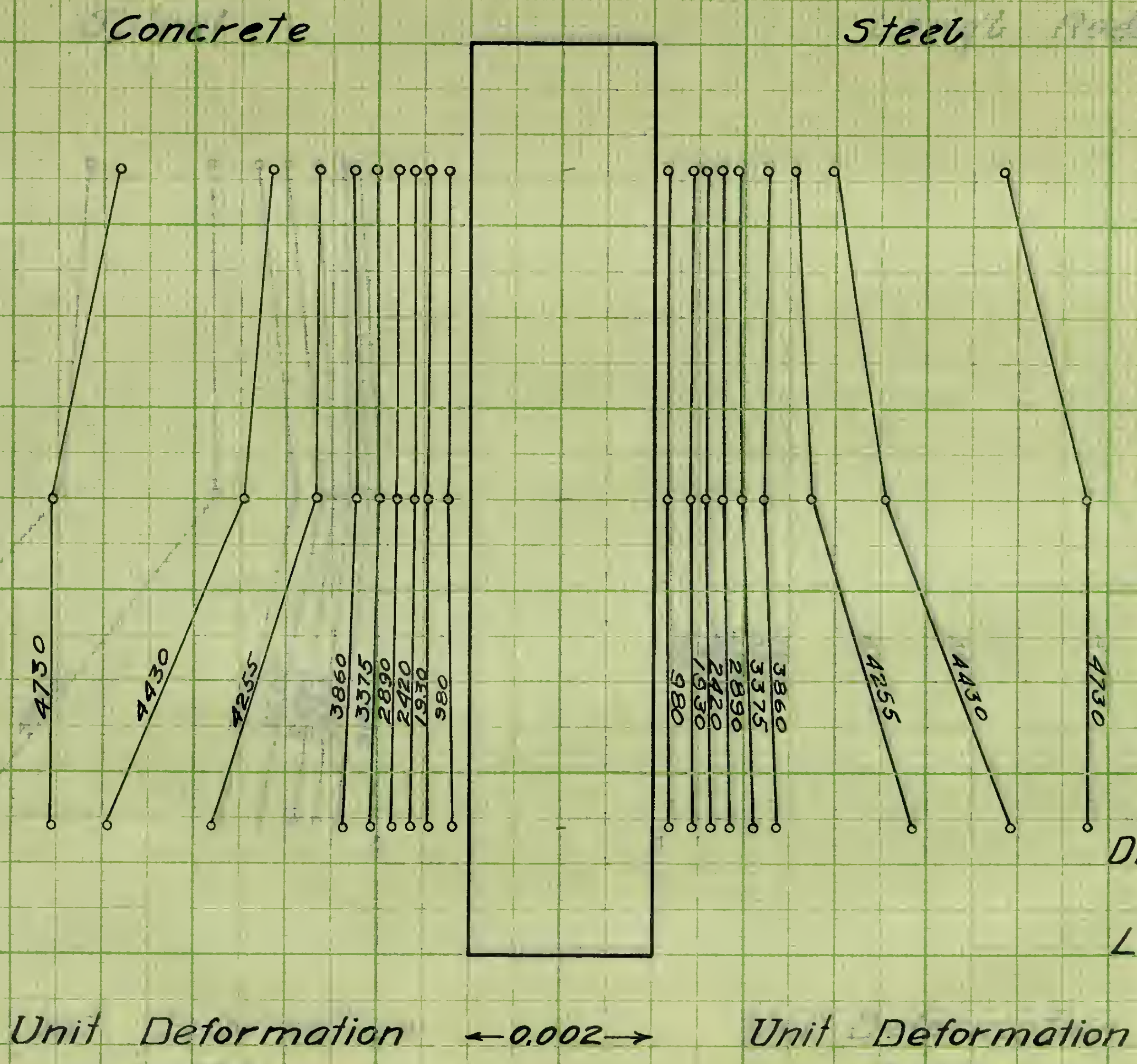
Col. 8990-2
Length 10'-0"
Comparison
of
Lat. & Long.
Steel
Deformations

COL. 8990-3
Length 10'-0"
DIST'N CURVES
for
LONG'L DEF'S.

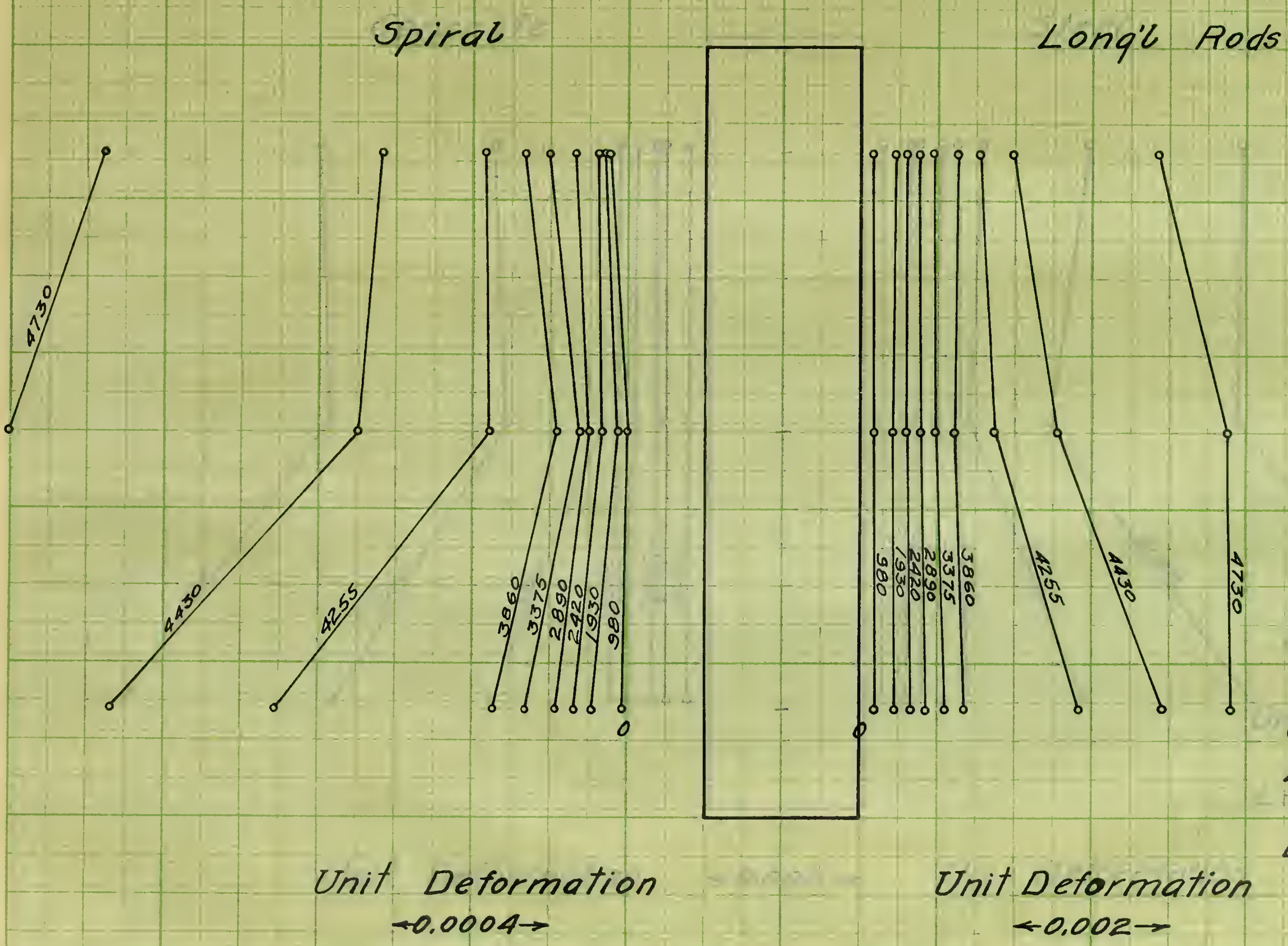




COL. 8990-3
Length-10'-0"
COMPARISON
OF
LAT. & LONG.
STEEL
DEFORMATIONS

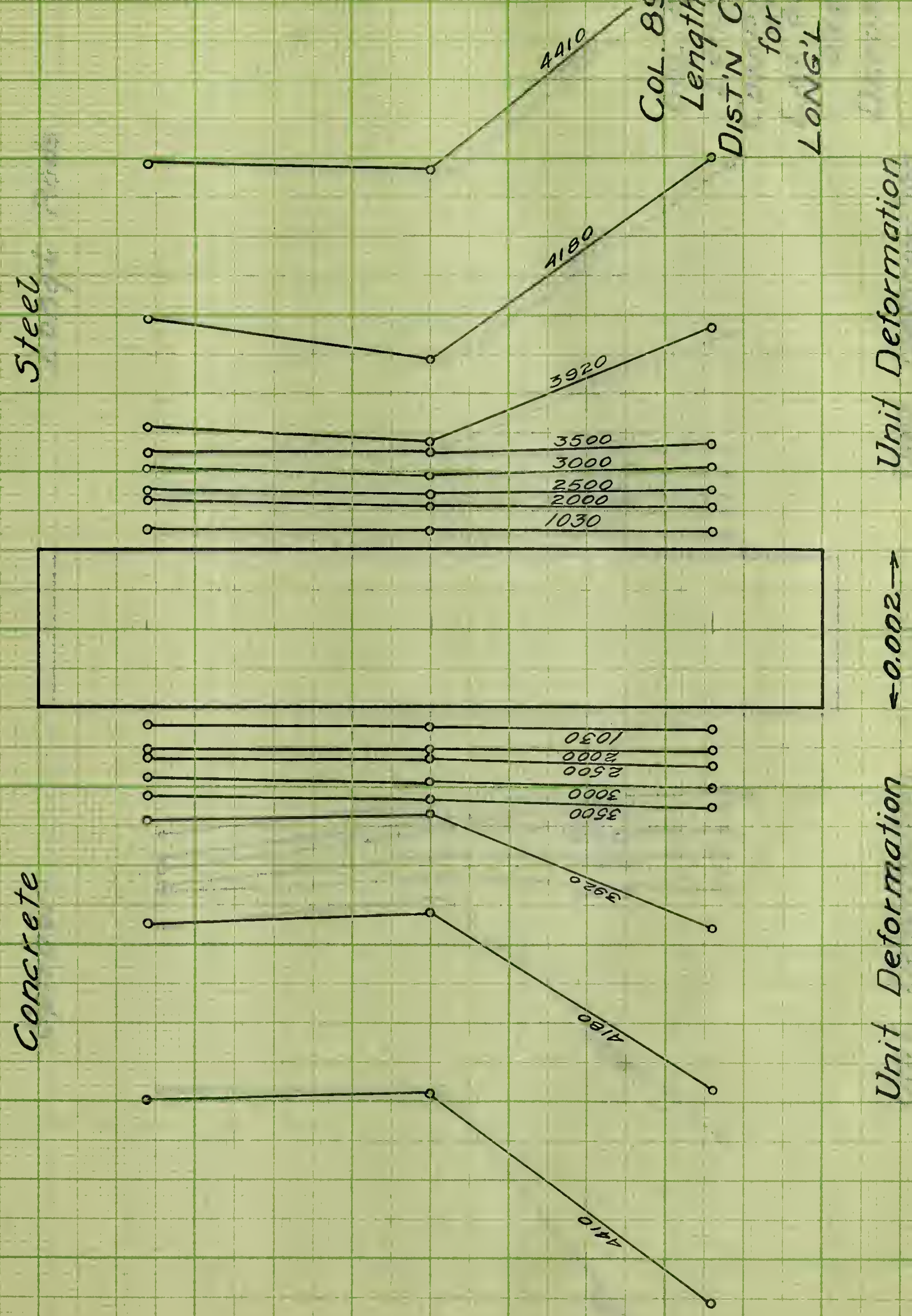


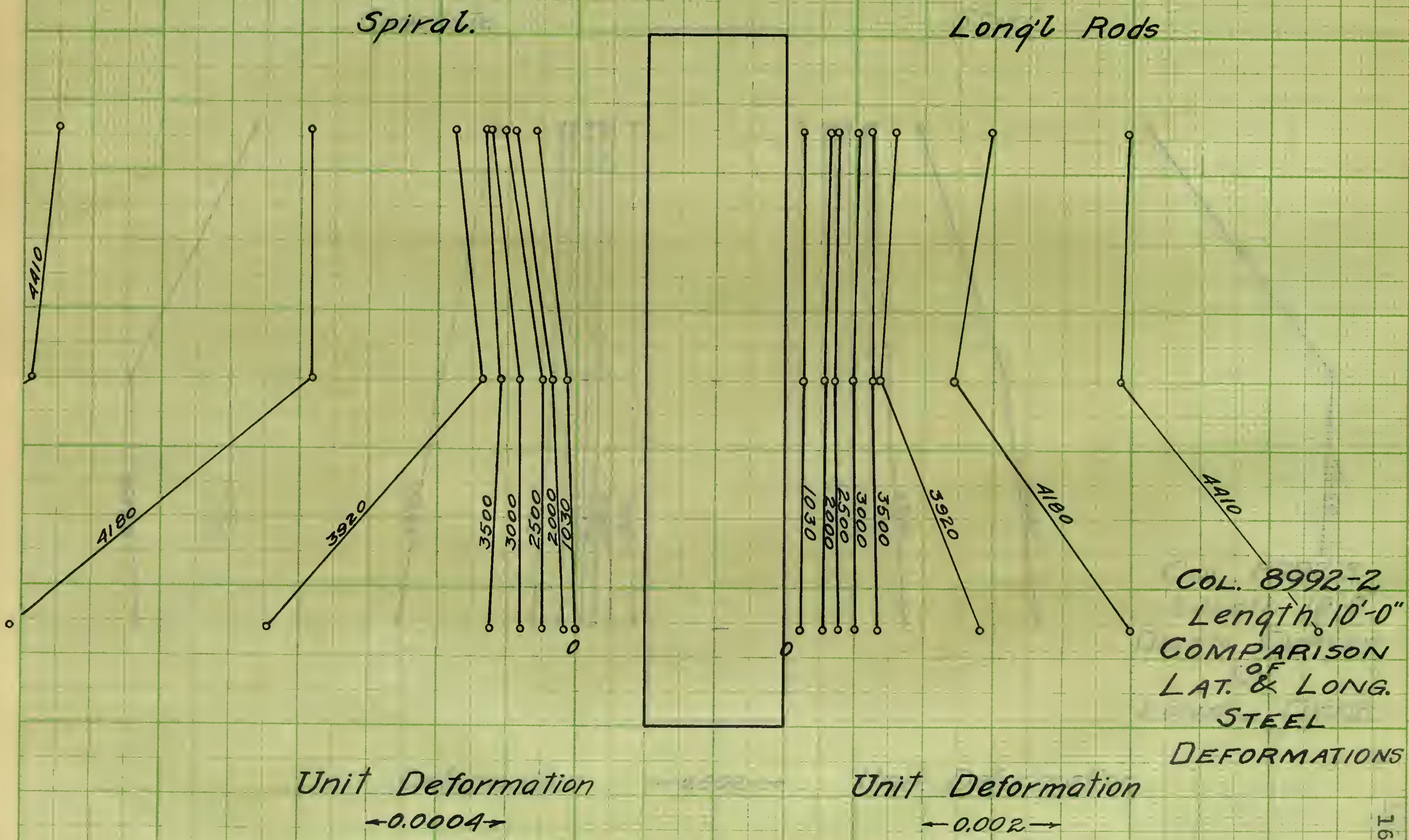
COL. 8992.1
Length 10'-0"
DIST'N CURVES
for
LONG'L DEF'S



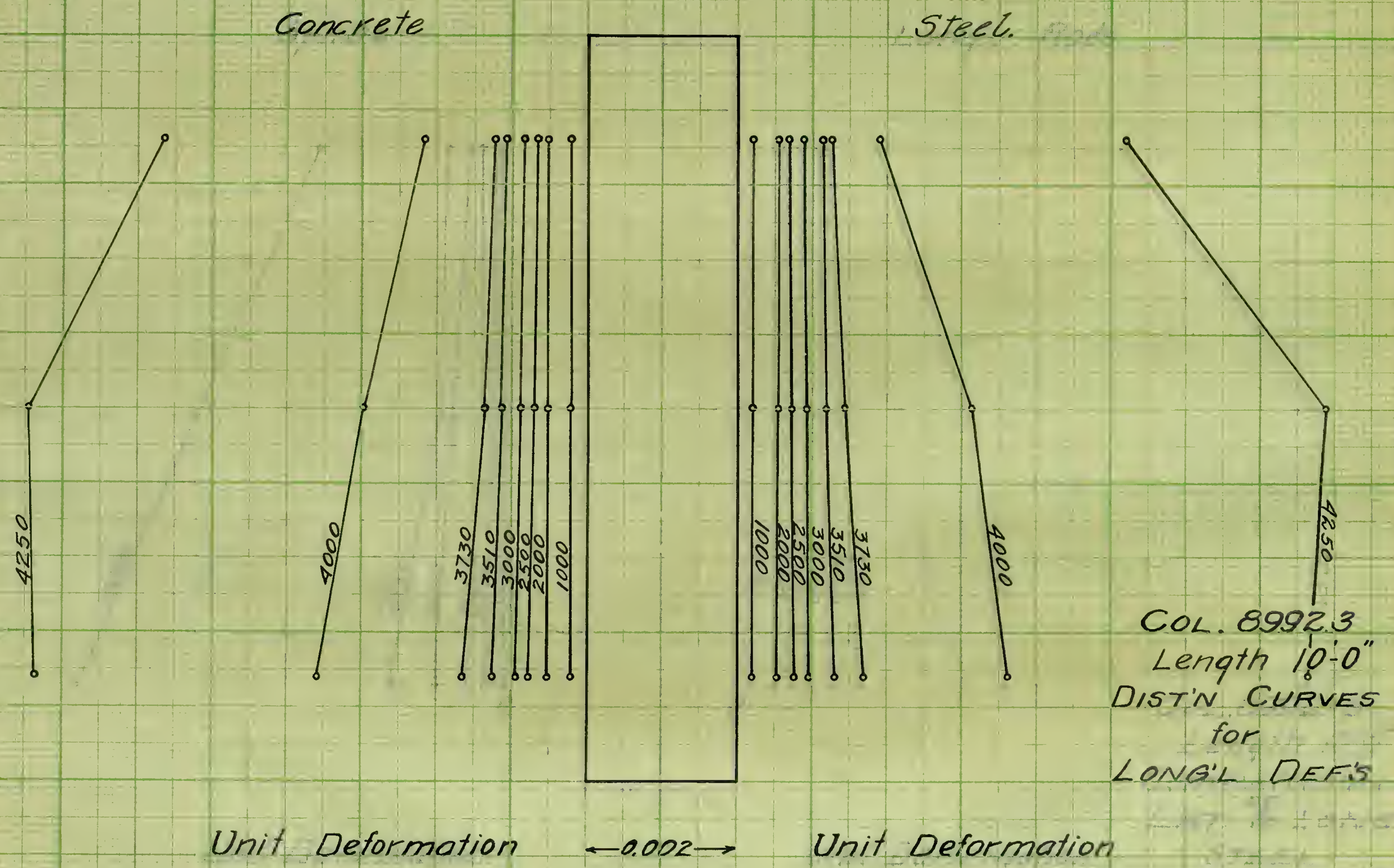
Col. 8992-1
Length 10'-0"
Comparison
of
Lat. & Long.
Steel
Deformations

COL. 8992.2
Length 10'-0"
DIST'N CURVES
for
LONG'L DEF'S

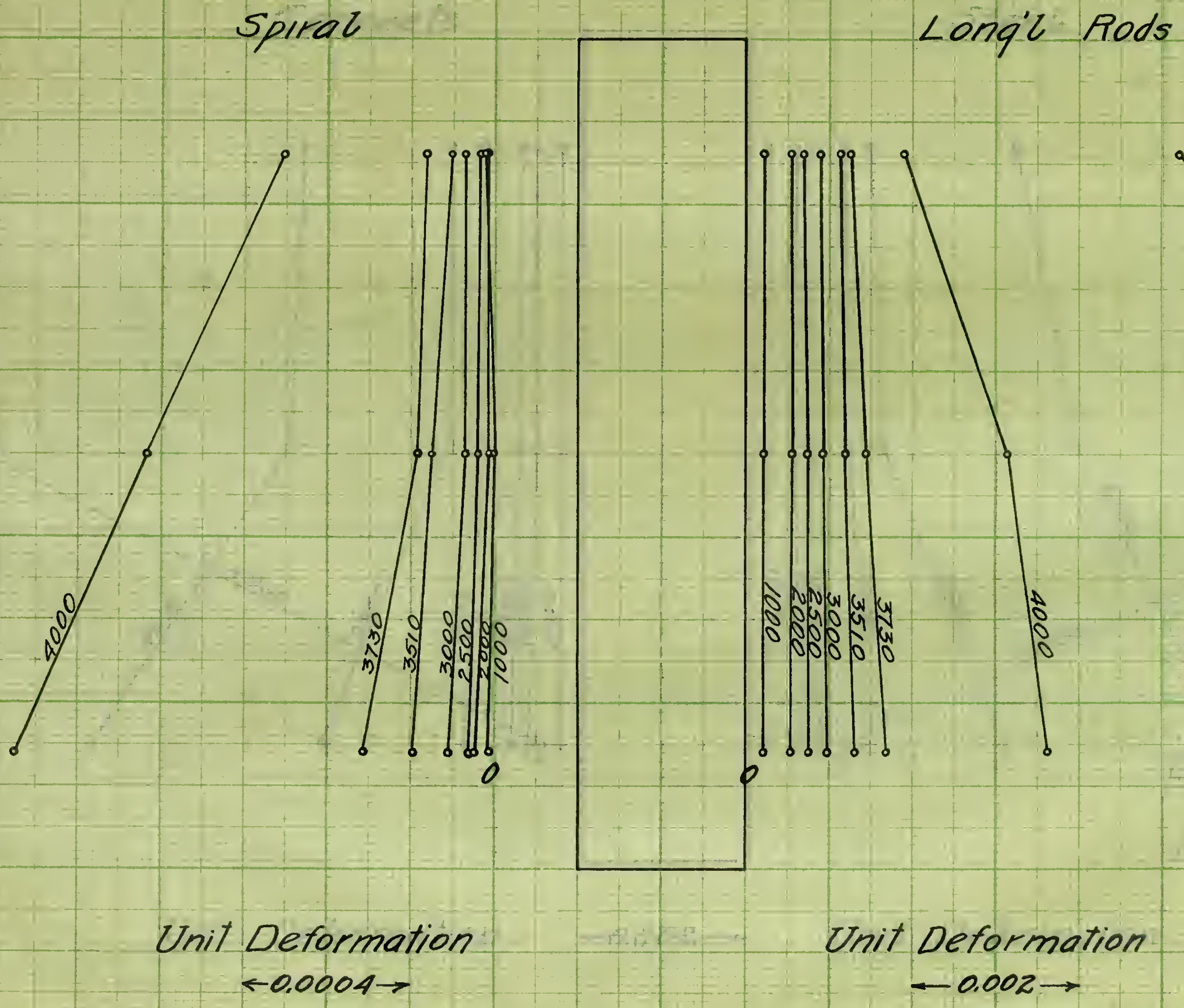




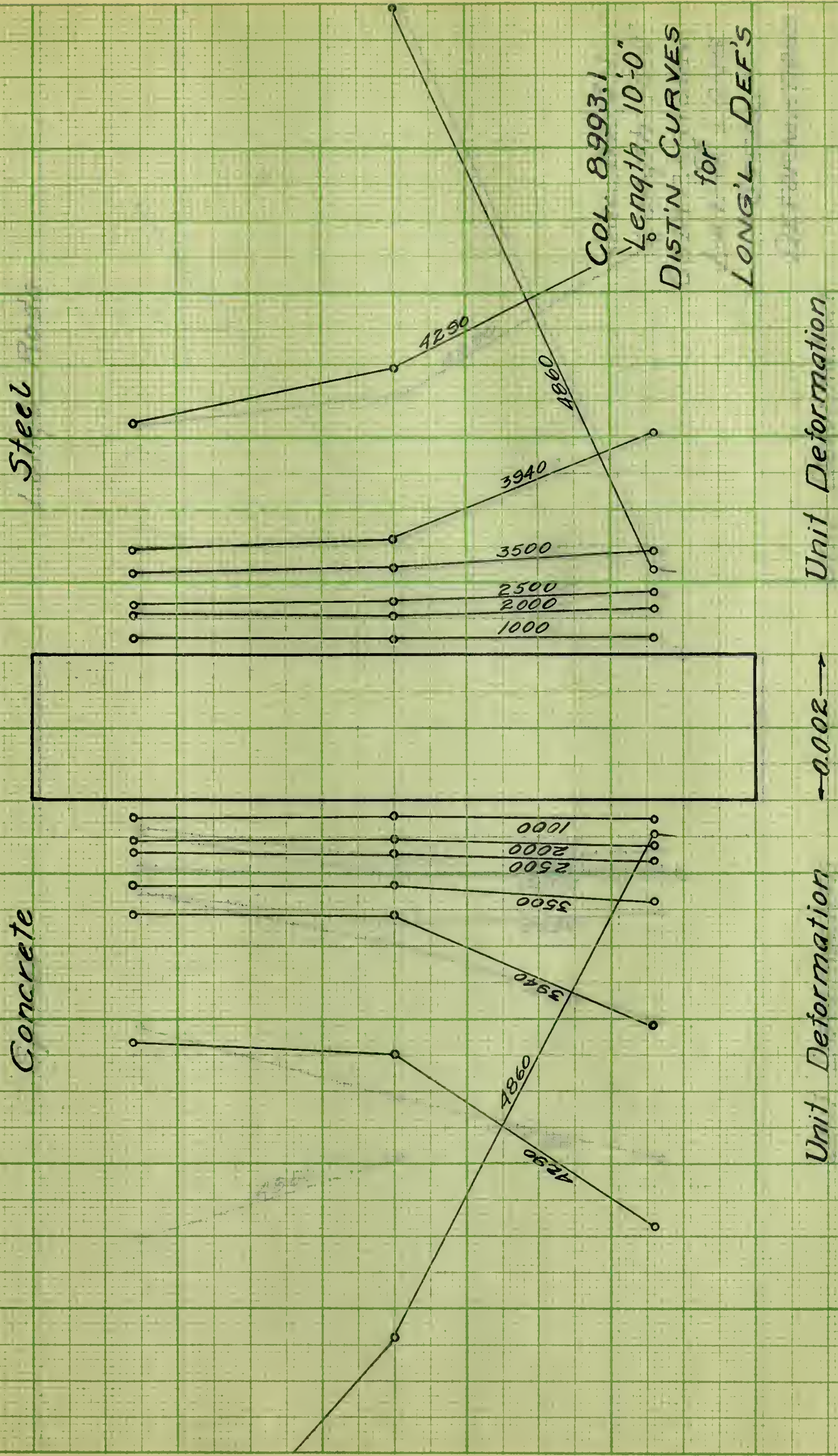
Col. 8992-2
Length 10'-0"
Comparison of Lat. & Long. Steel Deformations

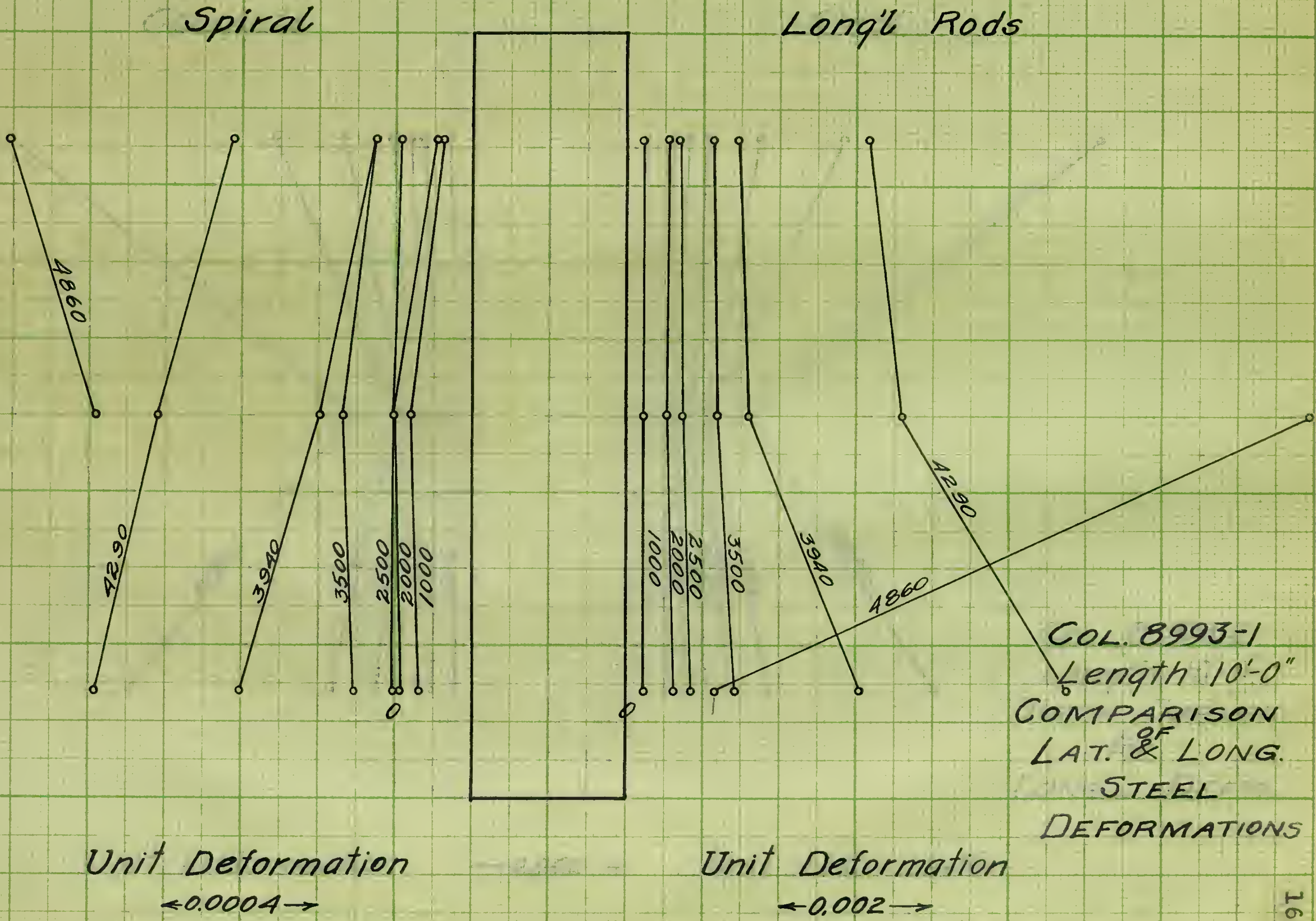


Col. 8992.3
Length 10'-0"
Dist'n Curves
for
Long'l Def's



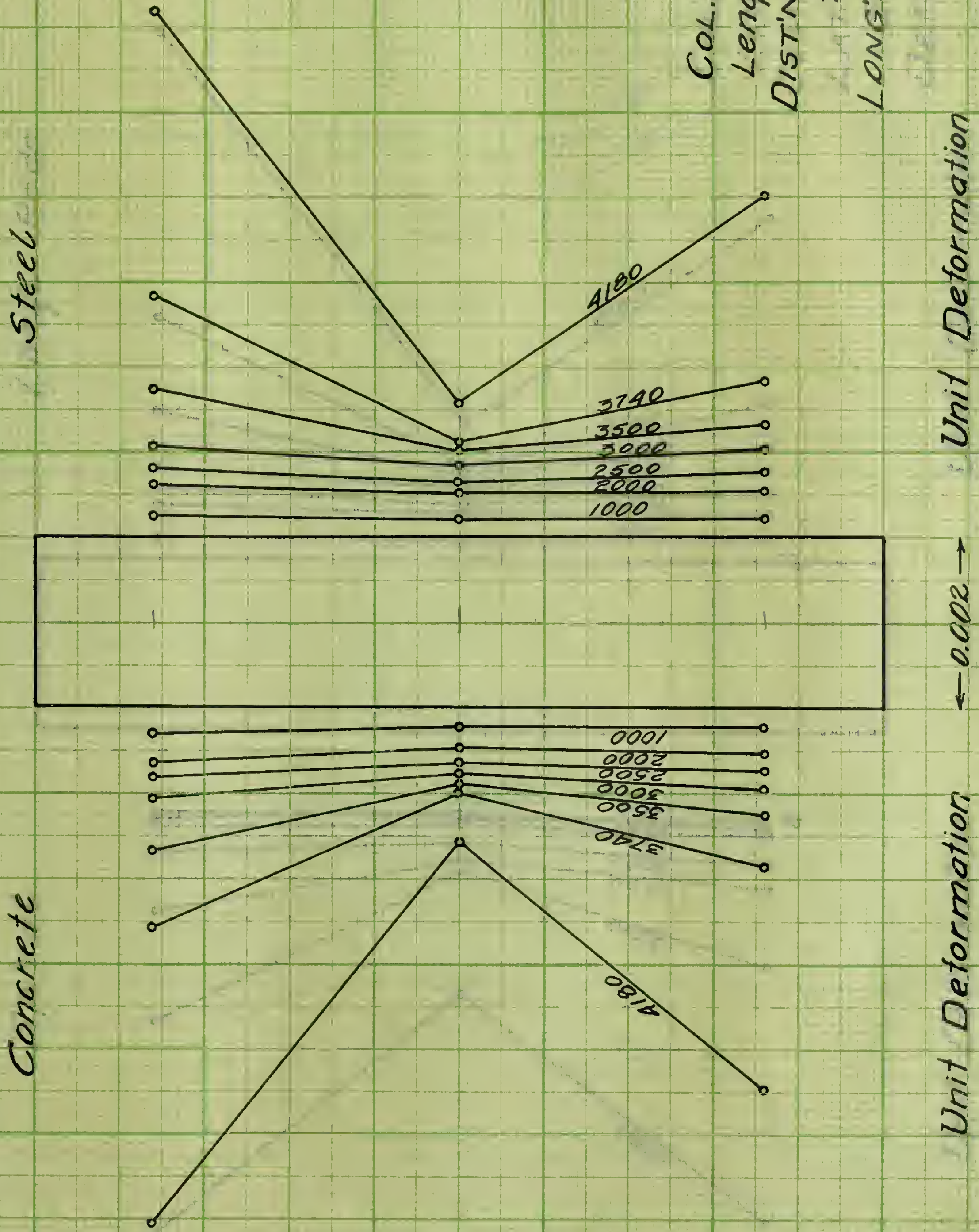
COL. 8992-3
Length 10'-0"
COMPARISON
OF
LAT. & LONG.
STEEL
DEFORMATIONS.

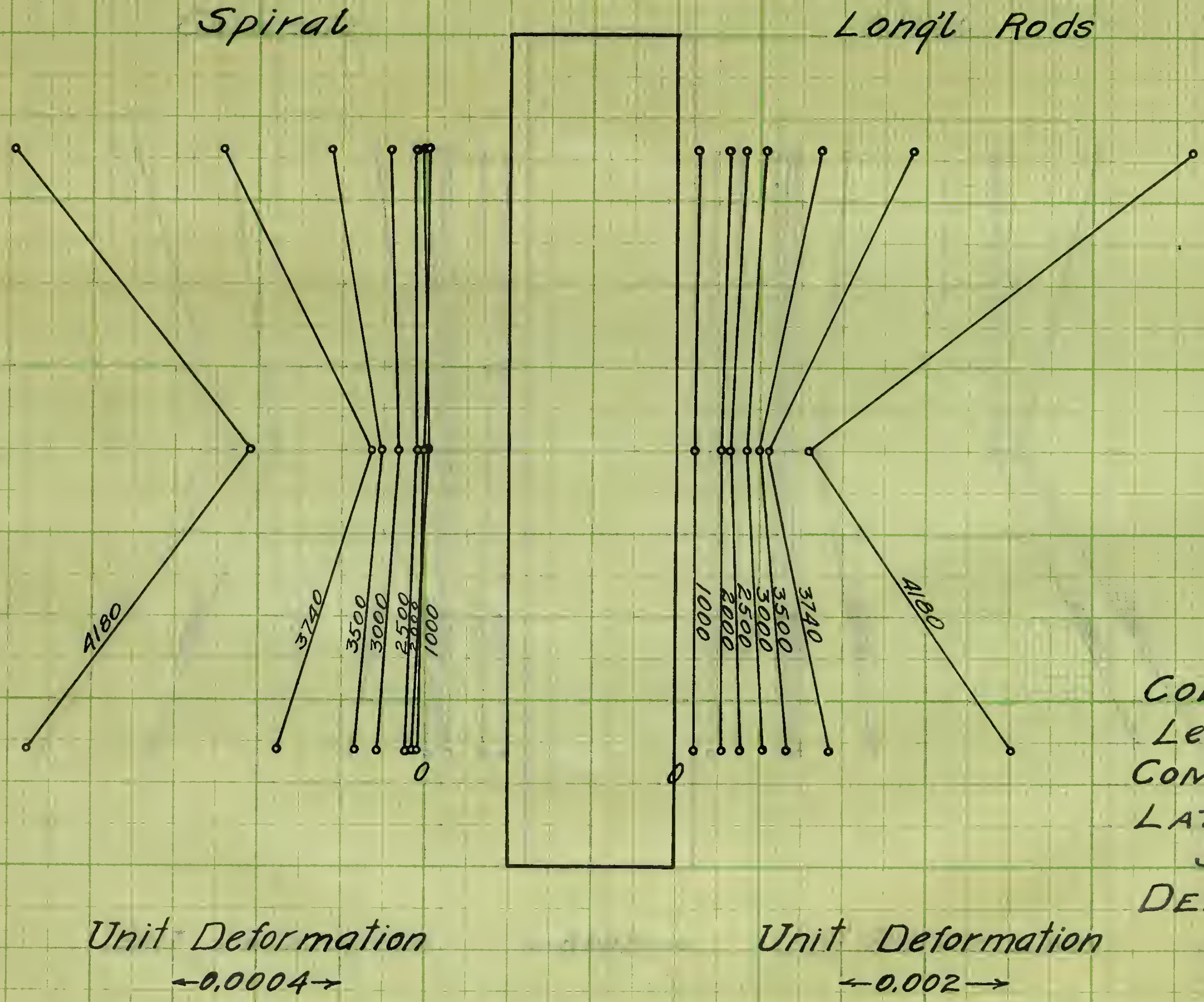

COL. 8993.1
Length 10'-0"
DIST'N CURVES
for
LONG'L DEF'S
Steel
Concrete
Unit Deformation
Unit Deformation
0.002
4290
4860
3940
3500
2500
2000
1000
1000
2000
2500
3500
3940
4860
4290



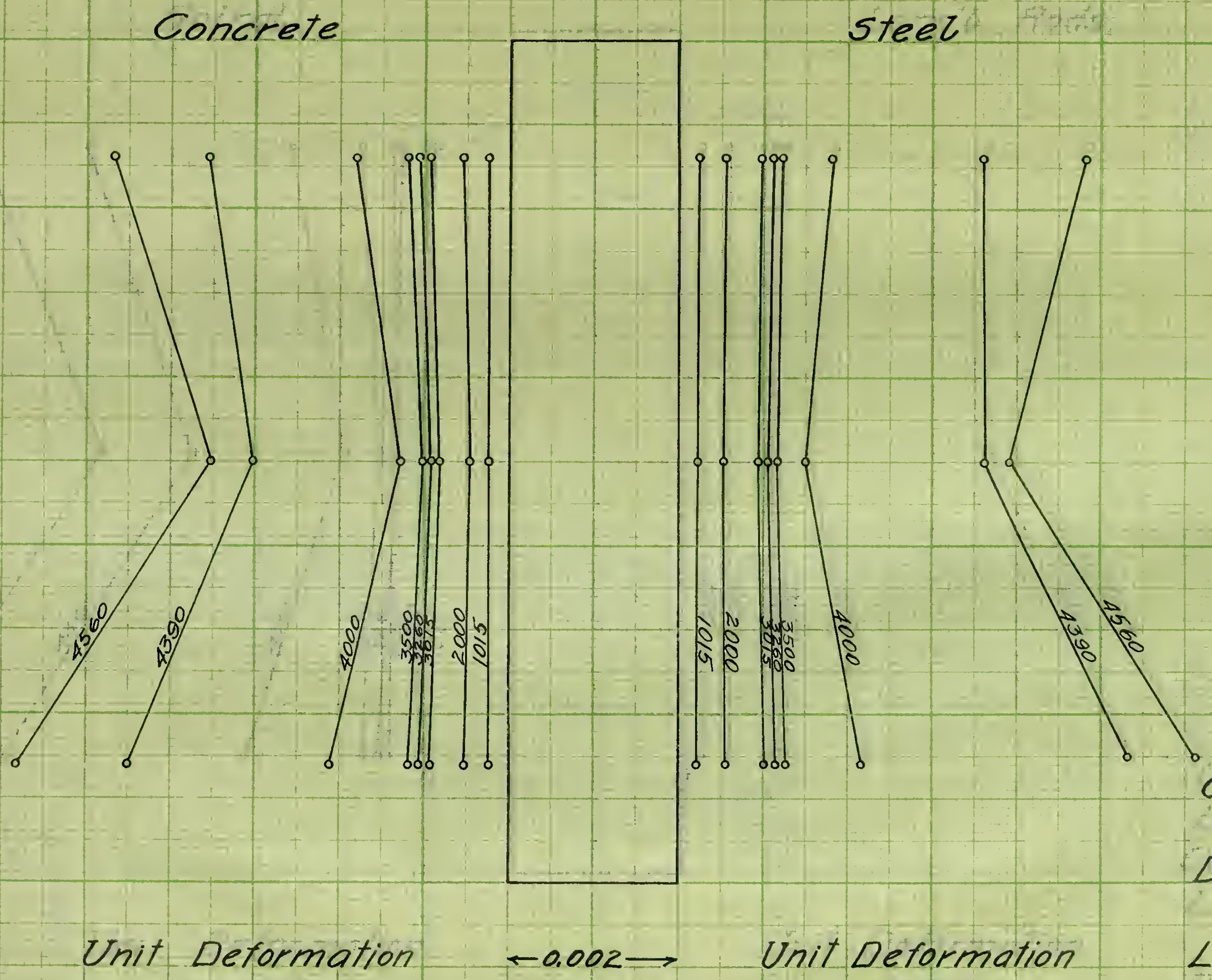
COL. 8993-1
Length 10'-0"
COMPARISON OF LAT. & LONG. STEEL DEFORMATIONS

Col. 8993.2
Length 10'-0"
Dist'n Curves
for
Long'l Def's.

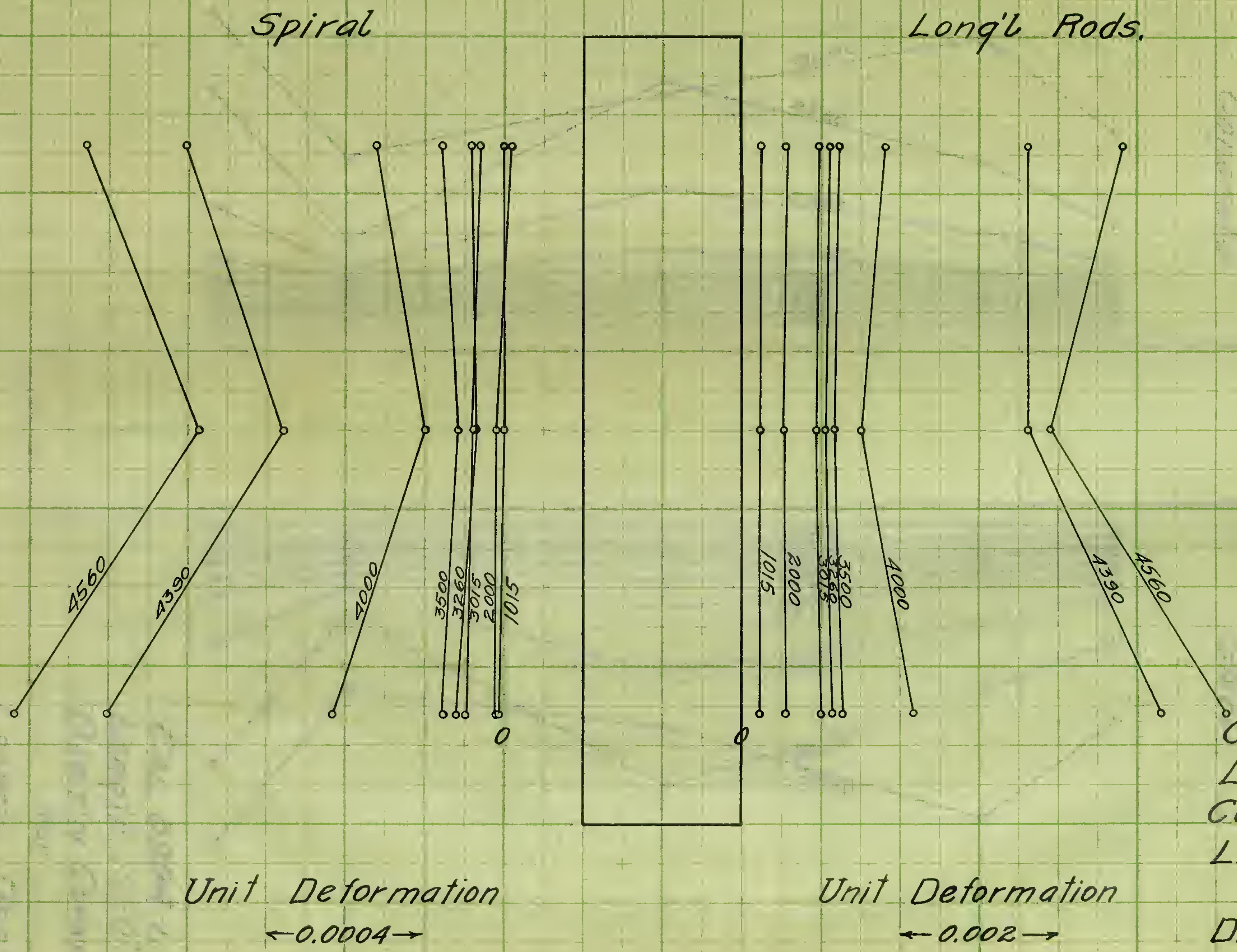




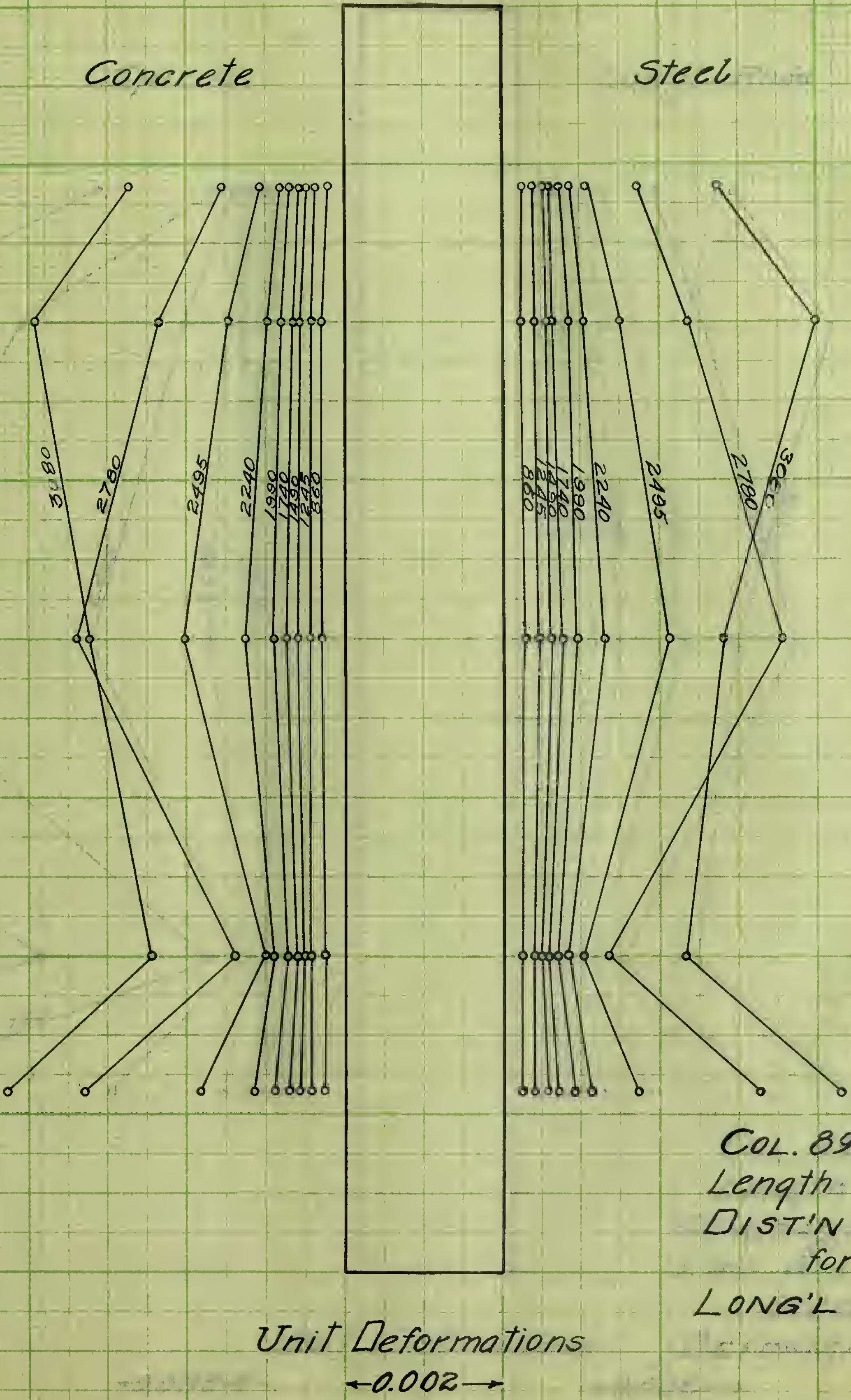
COL. 8993-2
Length 10'-0"
COMPARISON
OF
LAT. & LONG.
STEEL
DEFORMATIONS



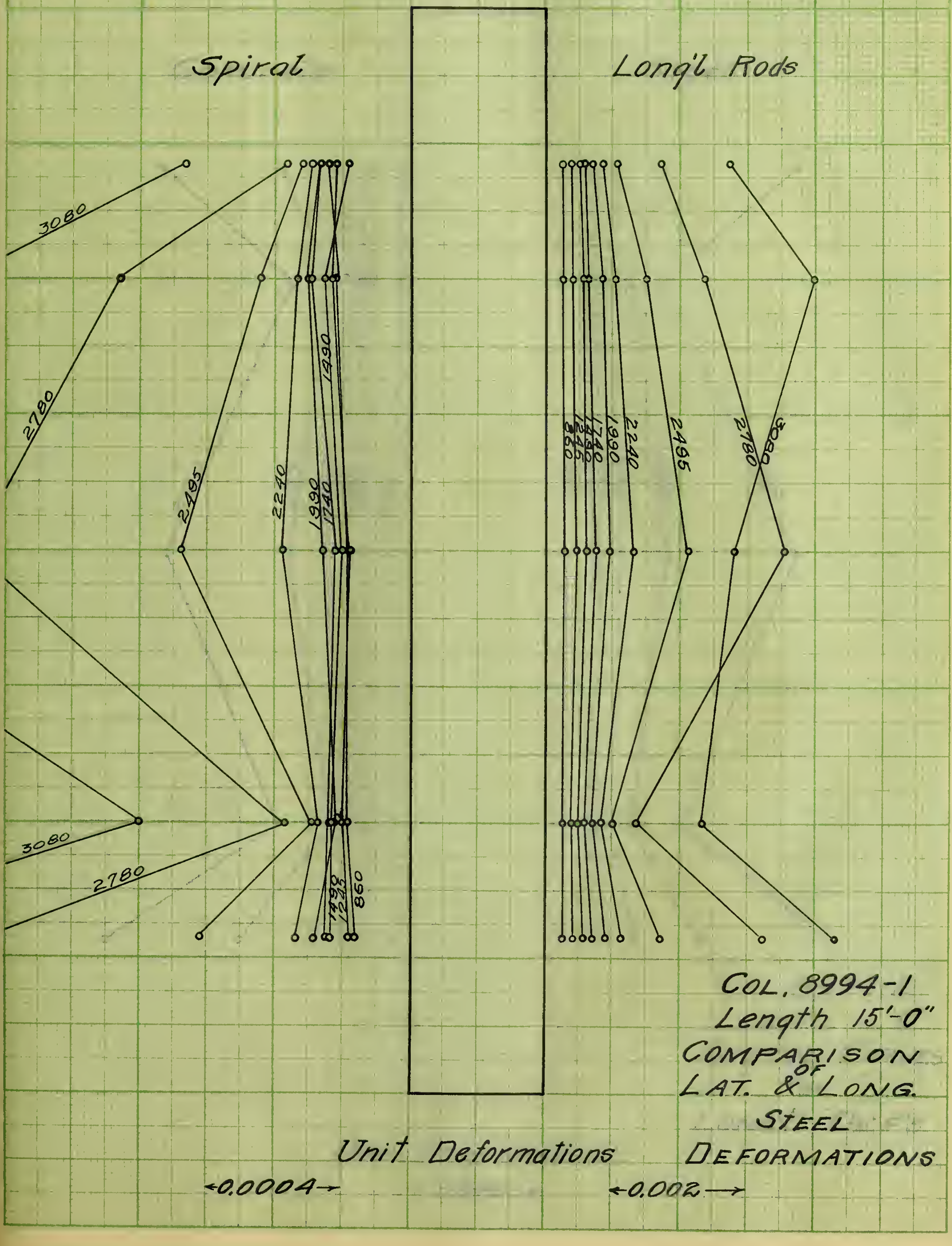
Col. 8993-3
Length 10'-0"
Dist'n Curves
for
Long'l Def's



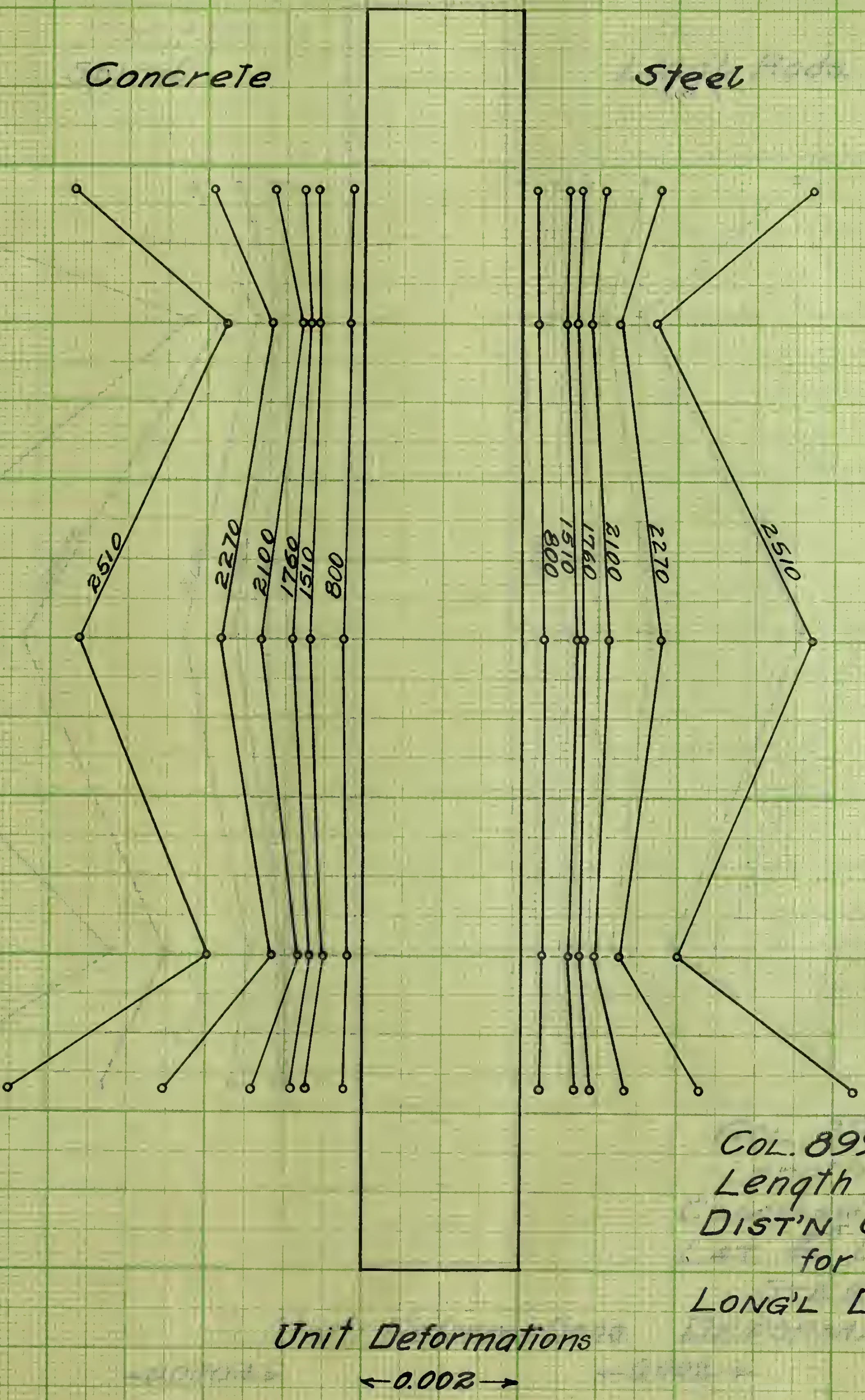
Col 8993-3
Length 10'-0"
COMPARISON
OF
LAT. & LONG.
STEEL
DEFORMATIONS



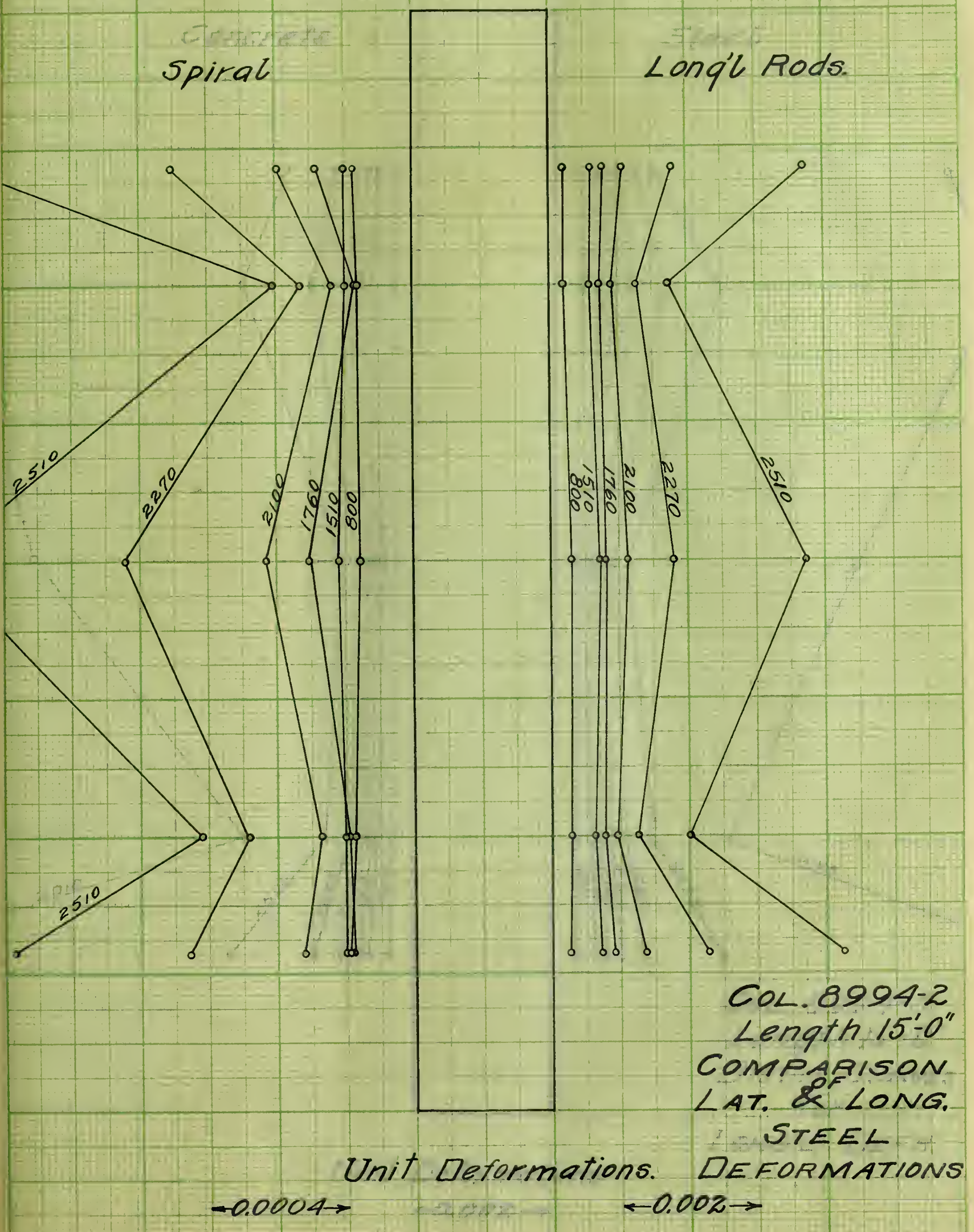
COL. 8994-1
Length 15'-0"
DIST'N CURVES
for
LONG'L DEF'S.



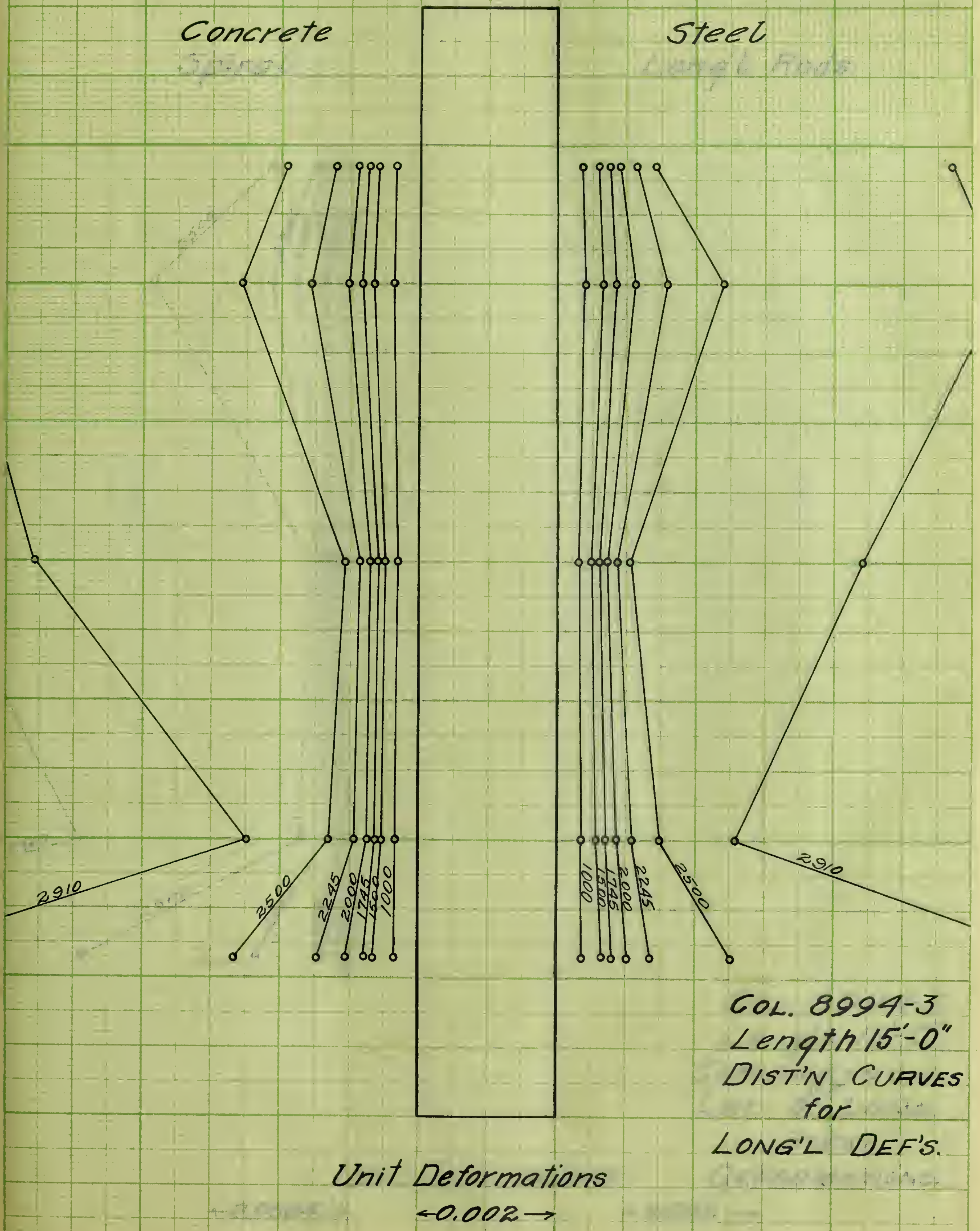
Col. 8994-1
Length 15'-0"
Comparison of
Lat. & Long.
Steel
Deformations



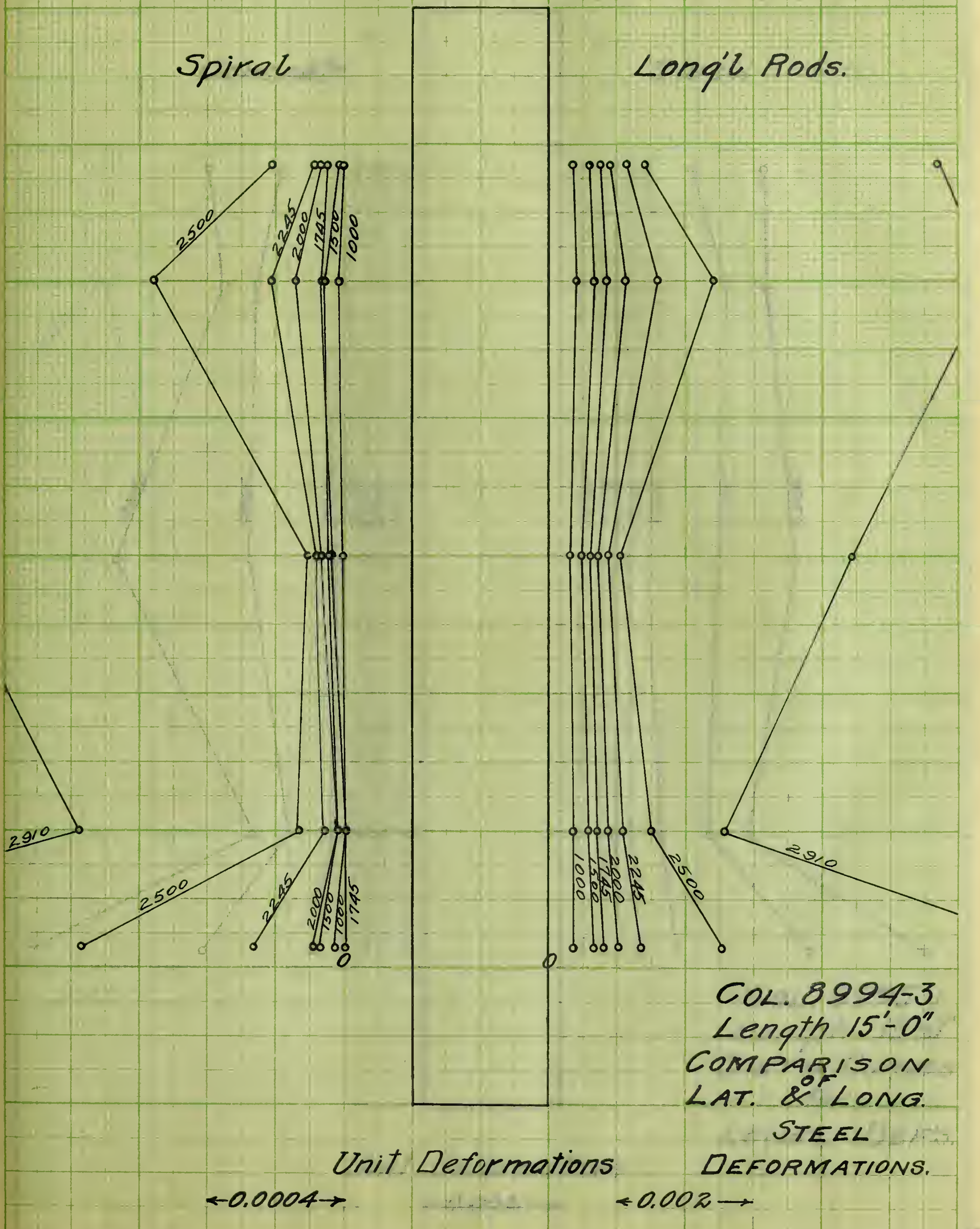
Col. 8994-2
Length 15'-0"
Dist'n Curves
for
Long'l Def's.



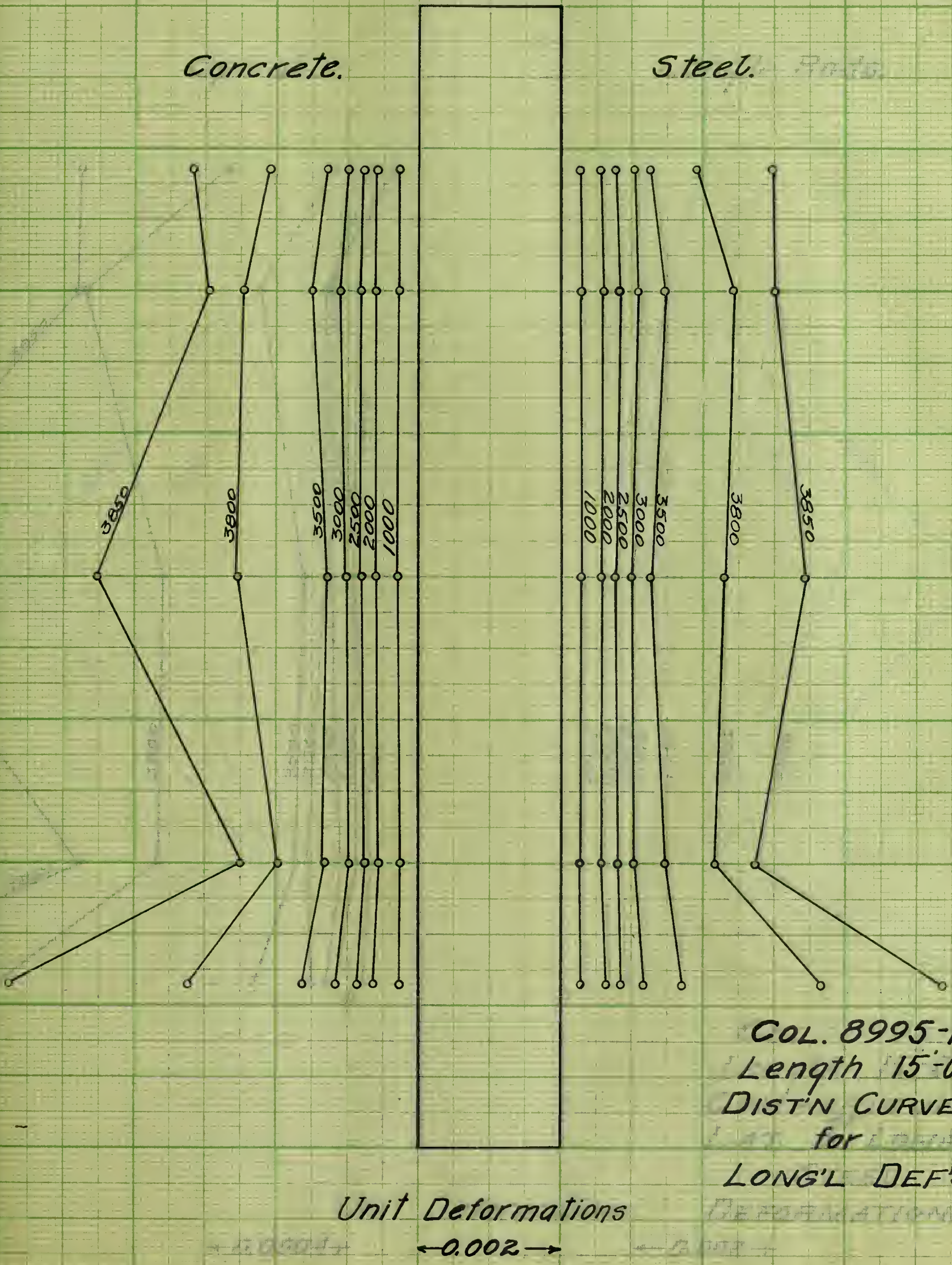
Col. 8994-2
Length 15'-0"
COMPARISON
OF
LAT. & LONG.
STEEL
DEFORMATIONS



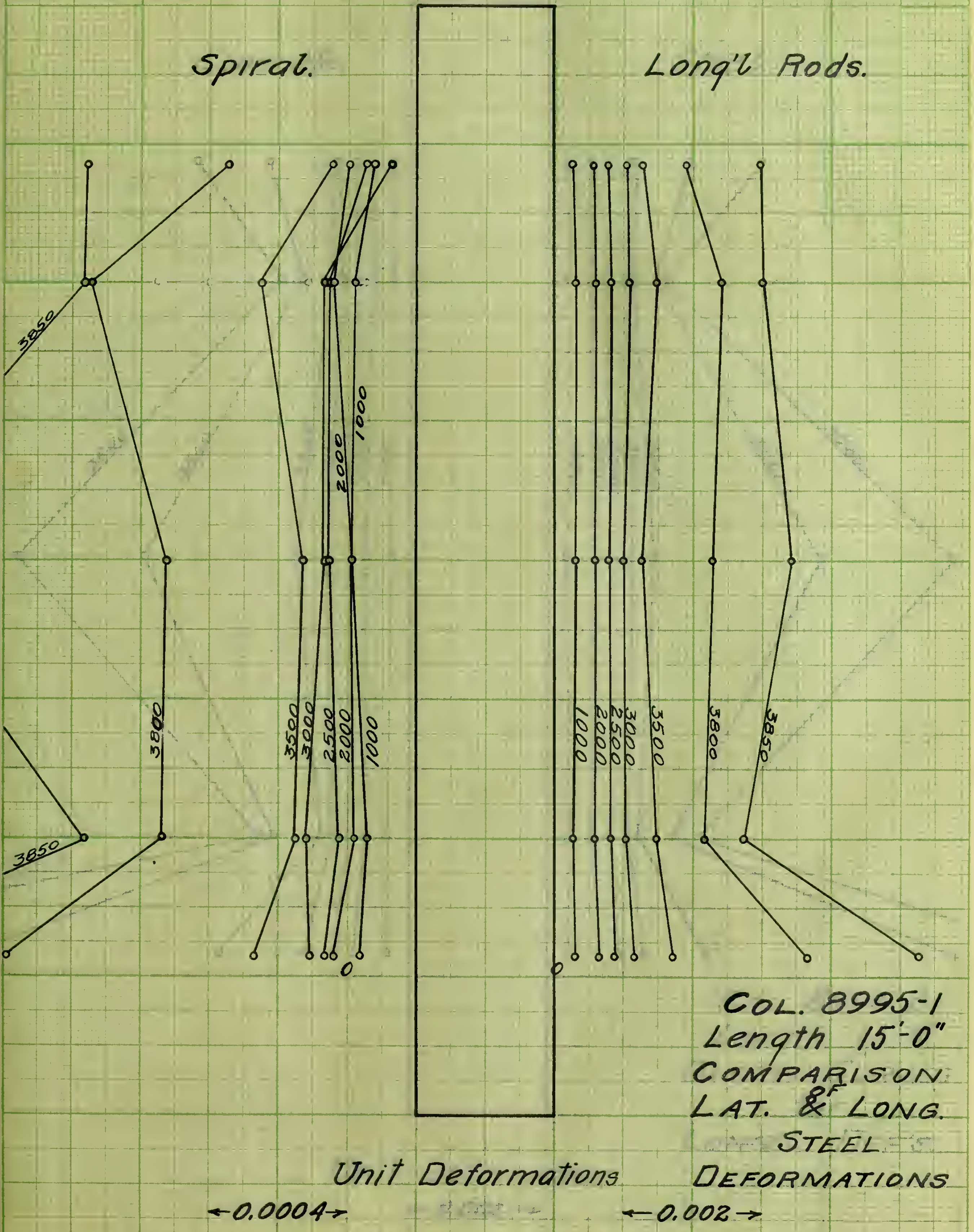
COL. 8994-3
Length 15'-0"
DIST'N CURVES
for
LONG'L DEF'S.



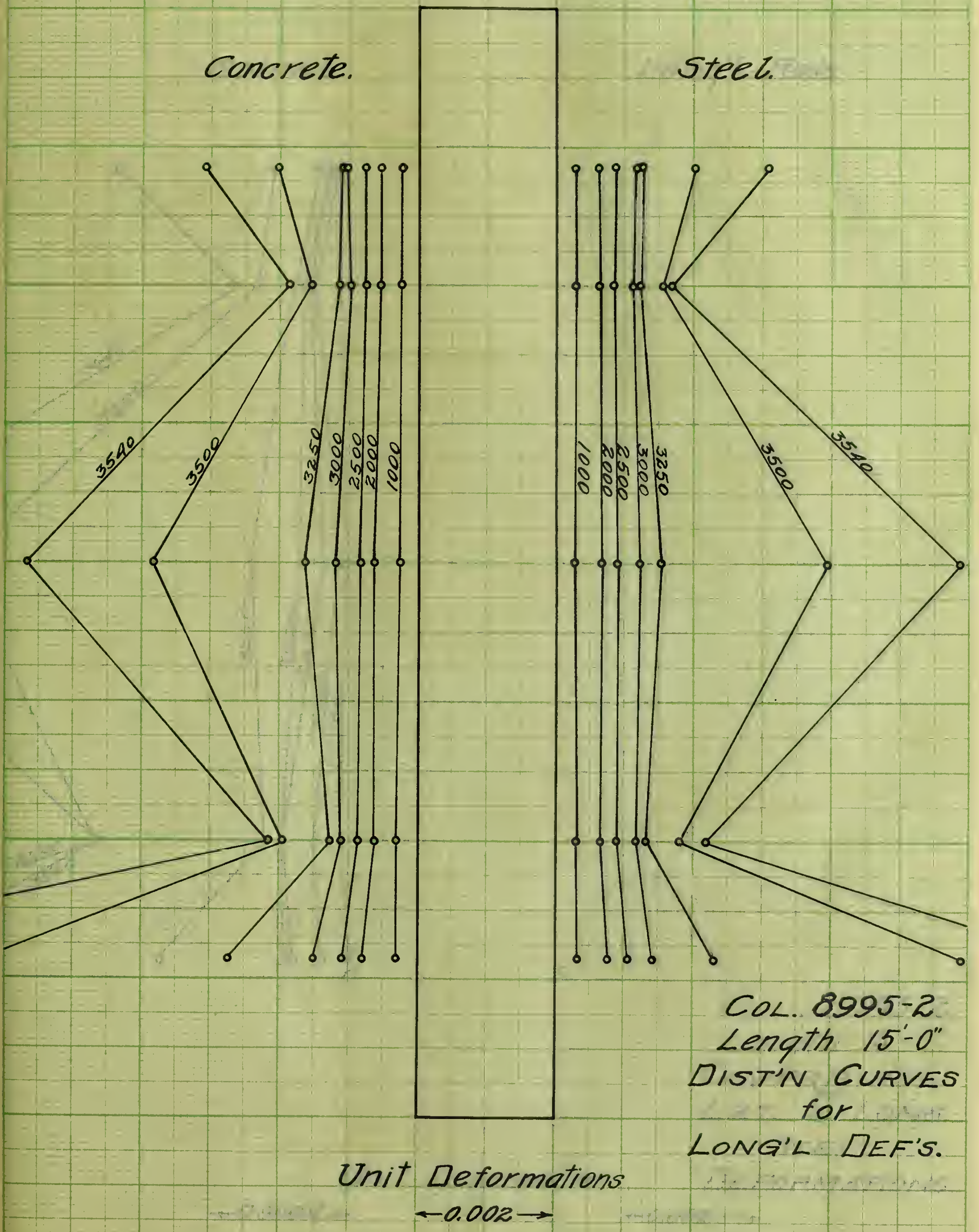
COL. 8994-3
Length 15'-0"
COMPARISON
OF
LAT. & LONG.
STEEL
DEFORMATIONS.



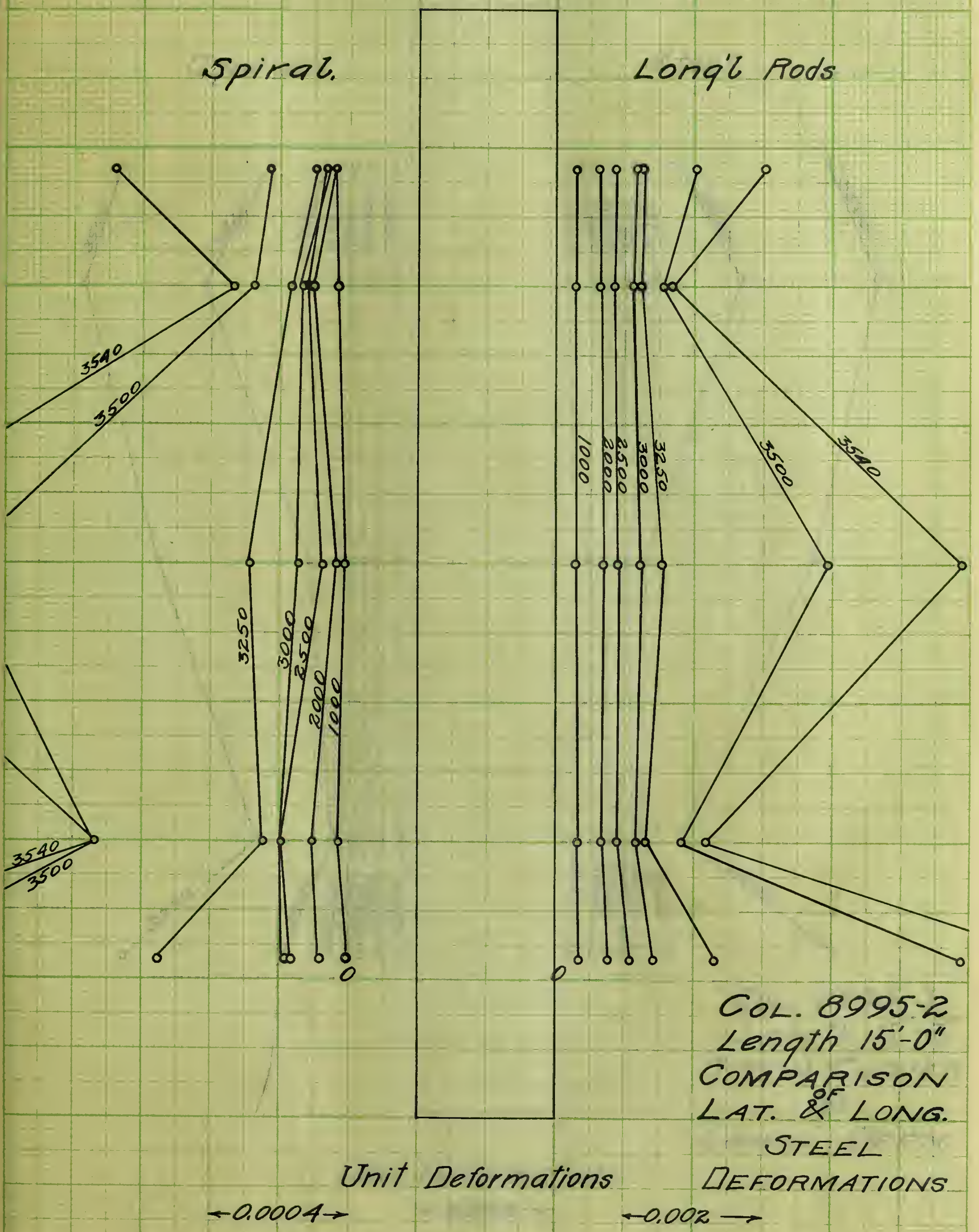
COL. 8995-1
Length 15'-0"
DIST'N CURVES
for
LONG'L DEF'S.



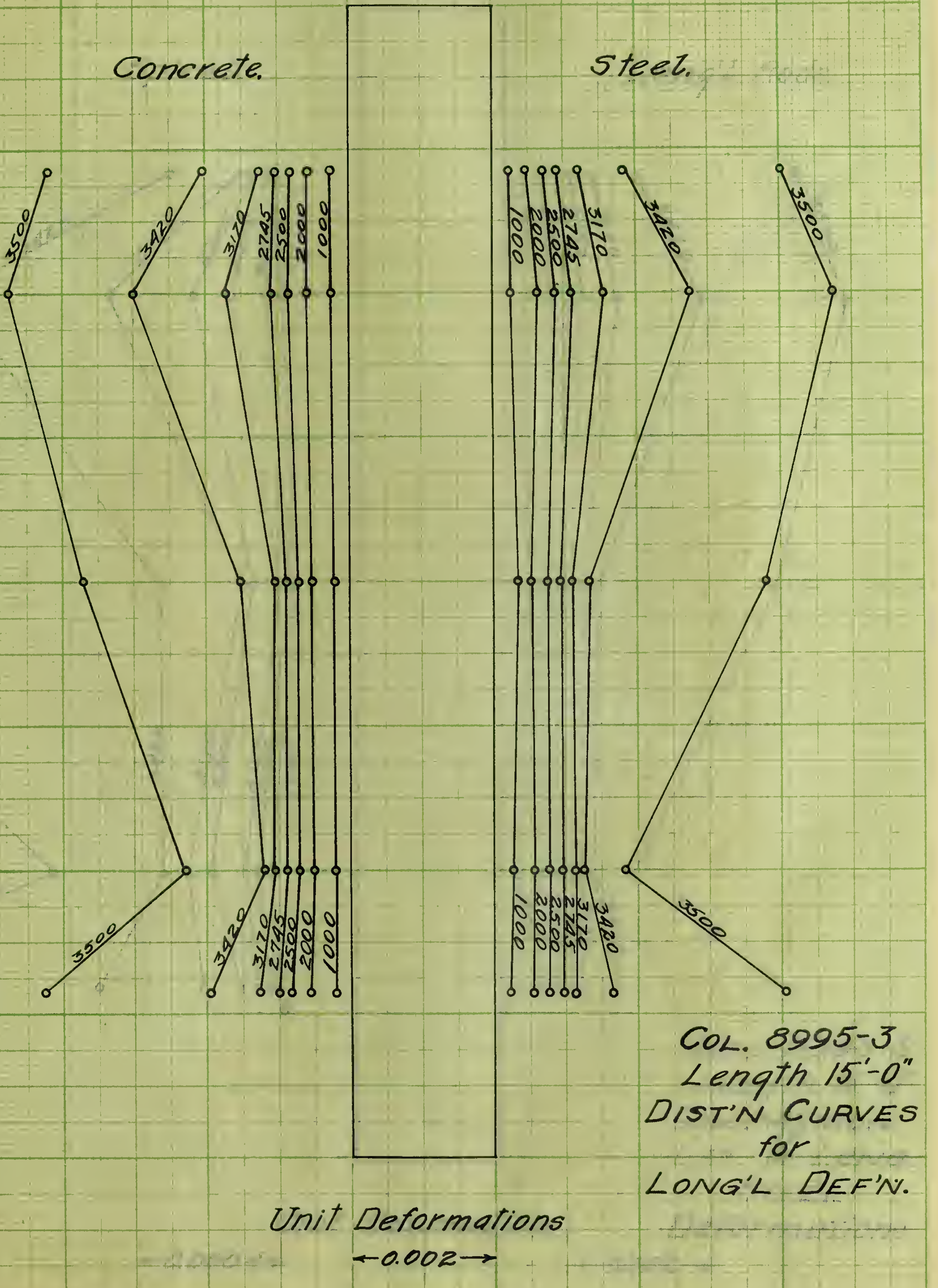
COL. 8995-1
Length 15'-0"
COMPARISON OF
LAT. & LONG.
STEEL
DEFORMATIONS



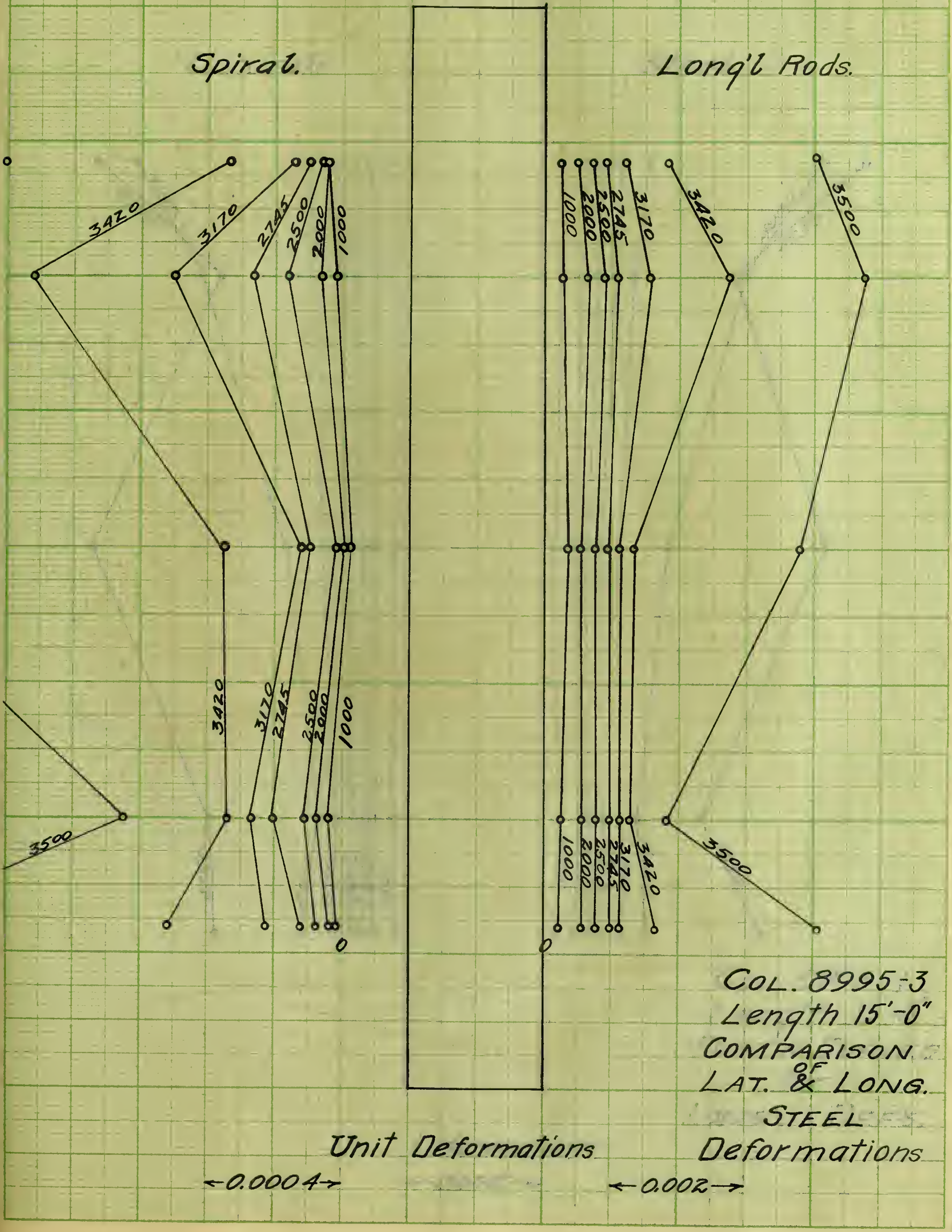
Col. 8995-2
Length 15'-0"
Dist'n Curves
for
Long'l Def's.



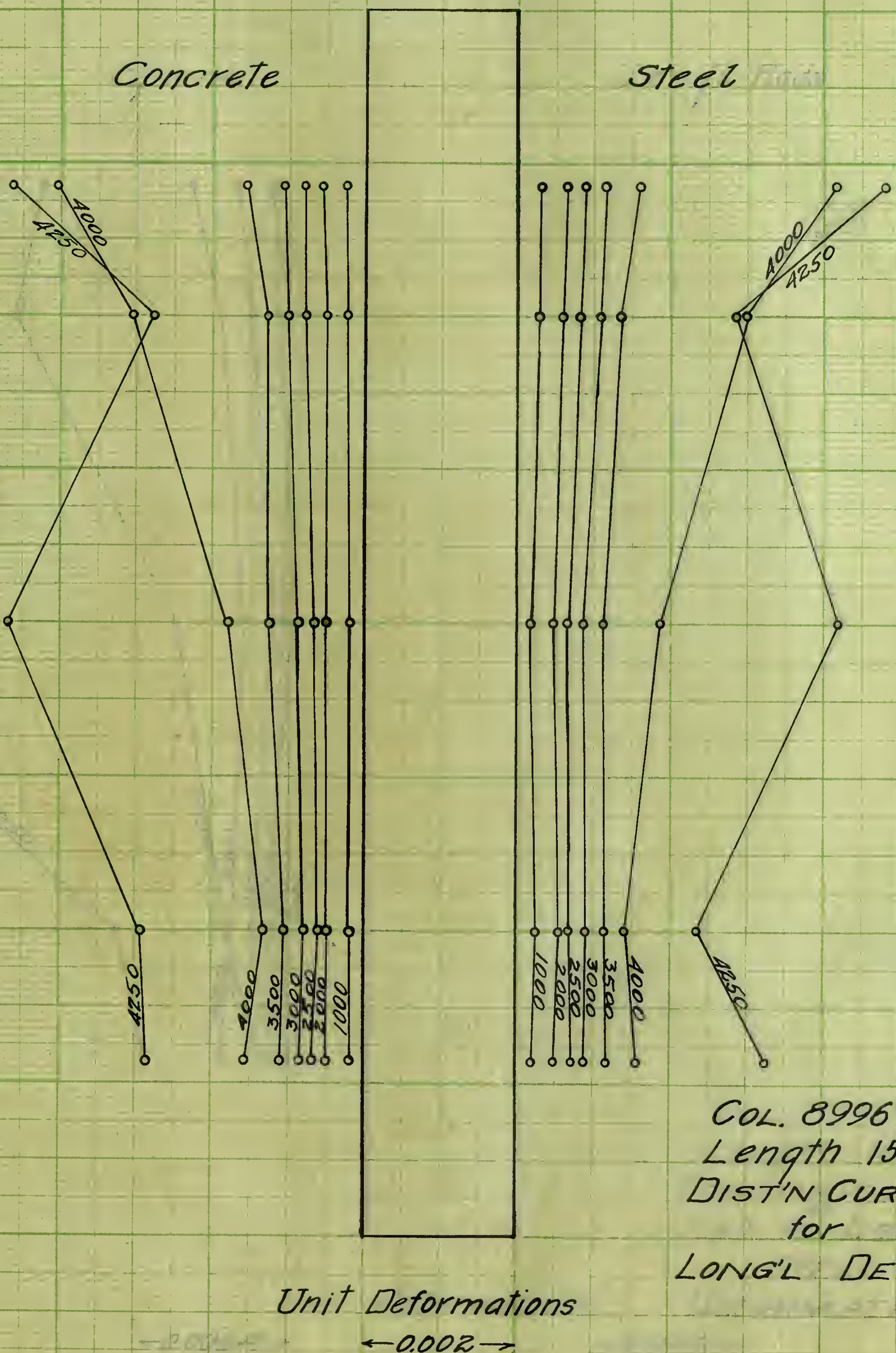
Col. 8995-2
Length 15'-0"
Comparison
of
Lat. & Long.
Steel
Deformations



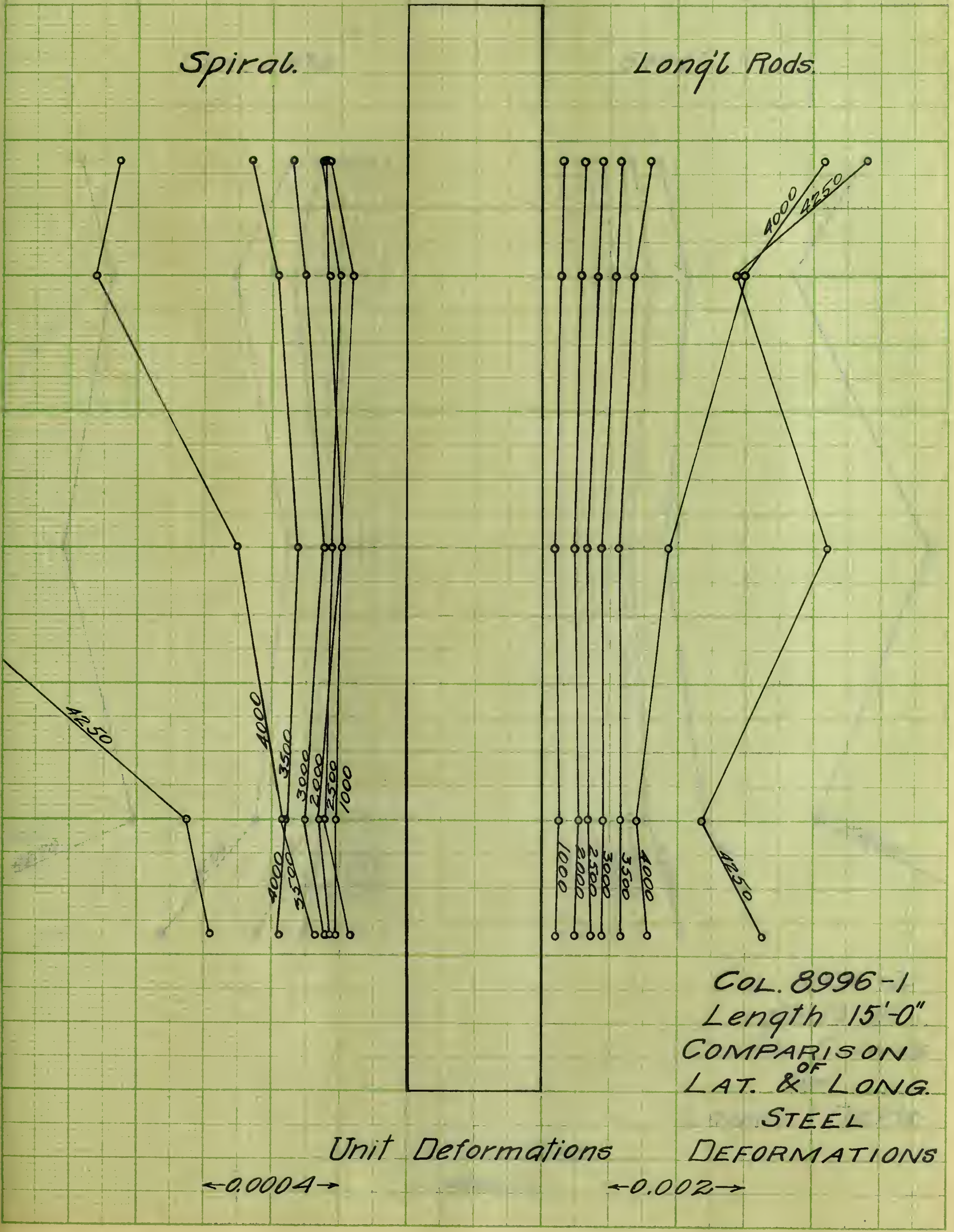
Col. 8995-3
Length 15'-0"
Dist'n Curves
for
Long'l Def'n.



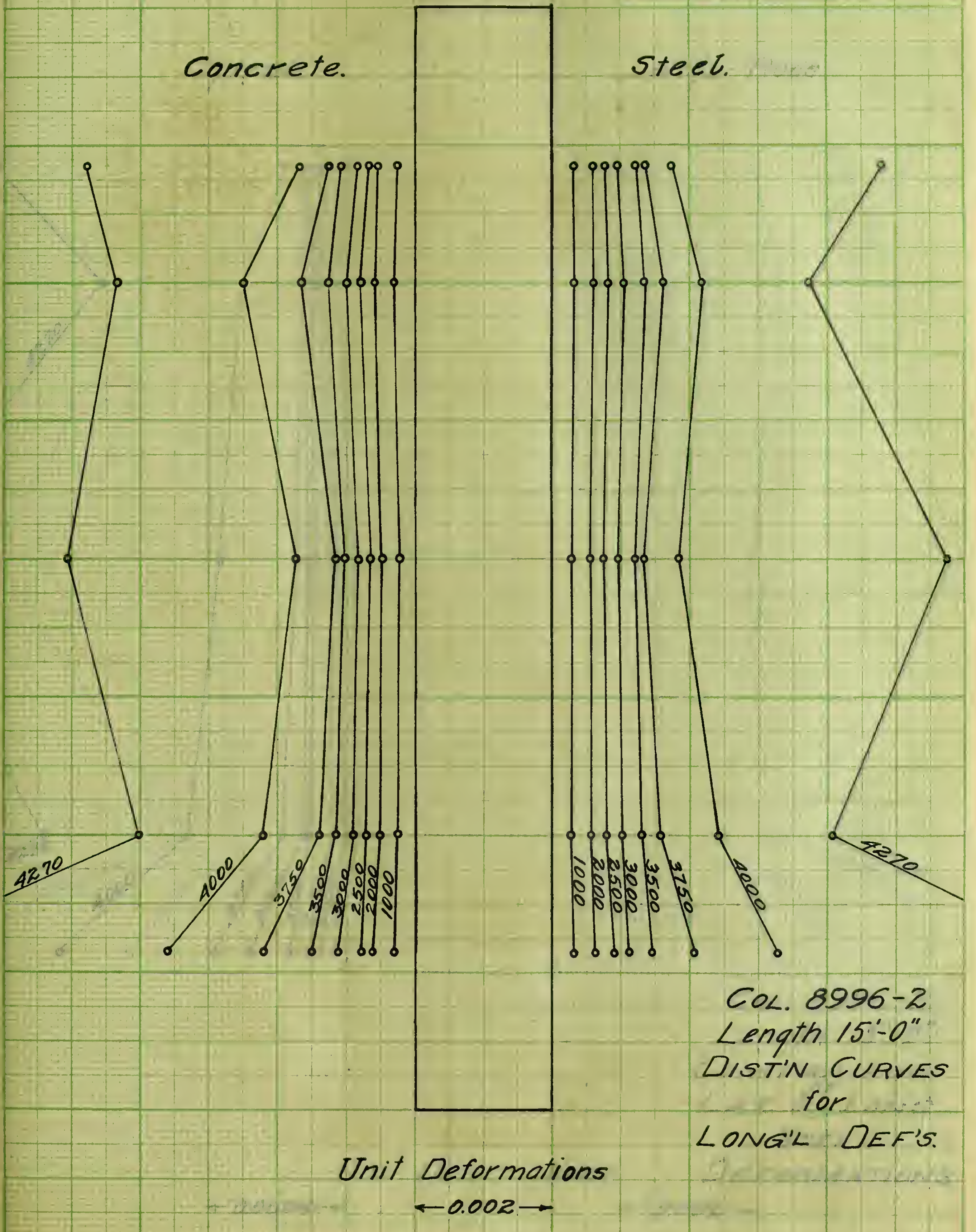
Col. 8995-3
Length 15'-0"
Comparison
of
Lat. & Long.
Steel
Deformations



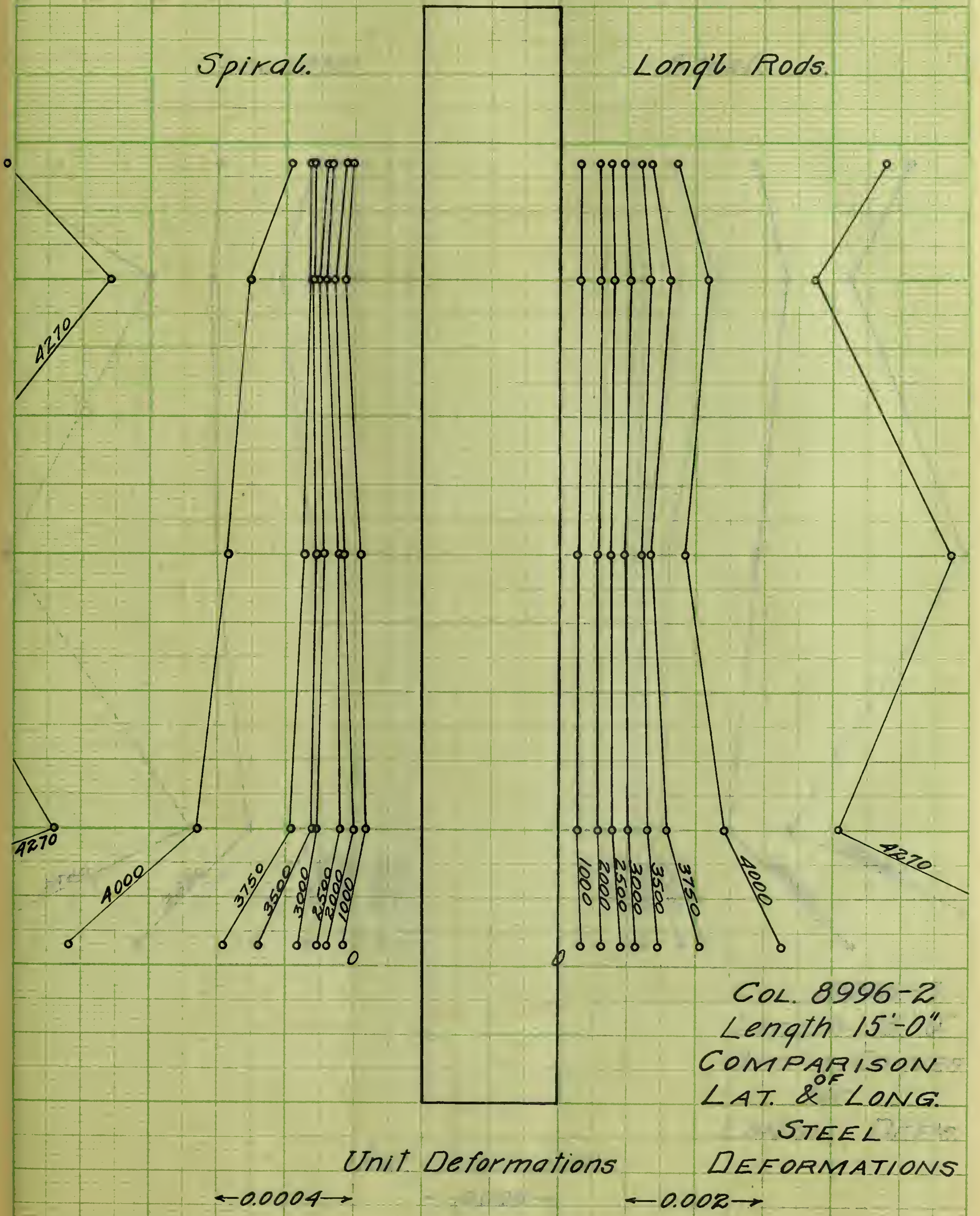
Col. 8996-1
Length 15'-0"
Dist'n Curves
for
Long'l Def's.



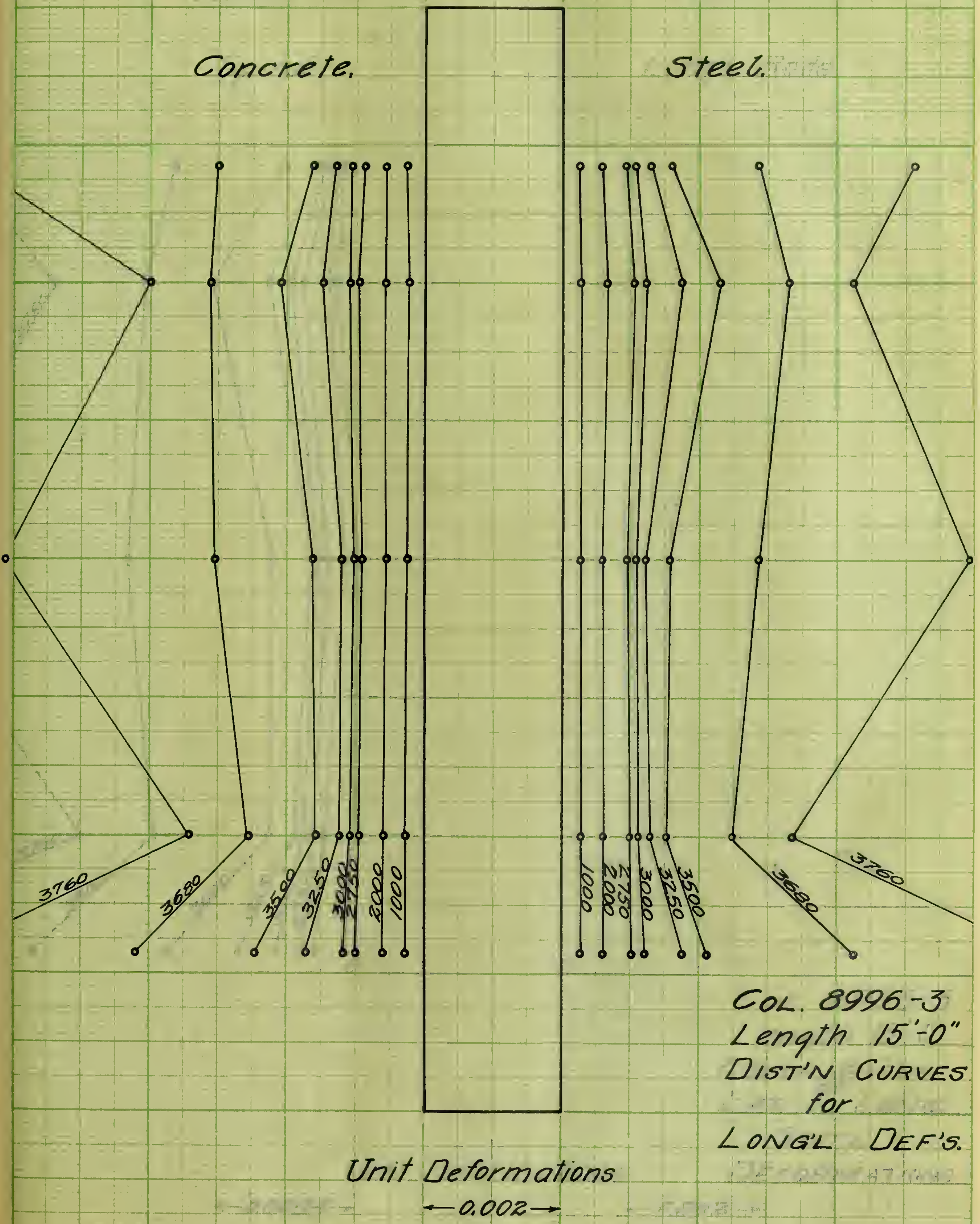
Col. 8996-1
Length 15'-0"
Comparison of
Lat. & Long.
Steel
Deformations



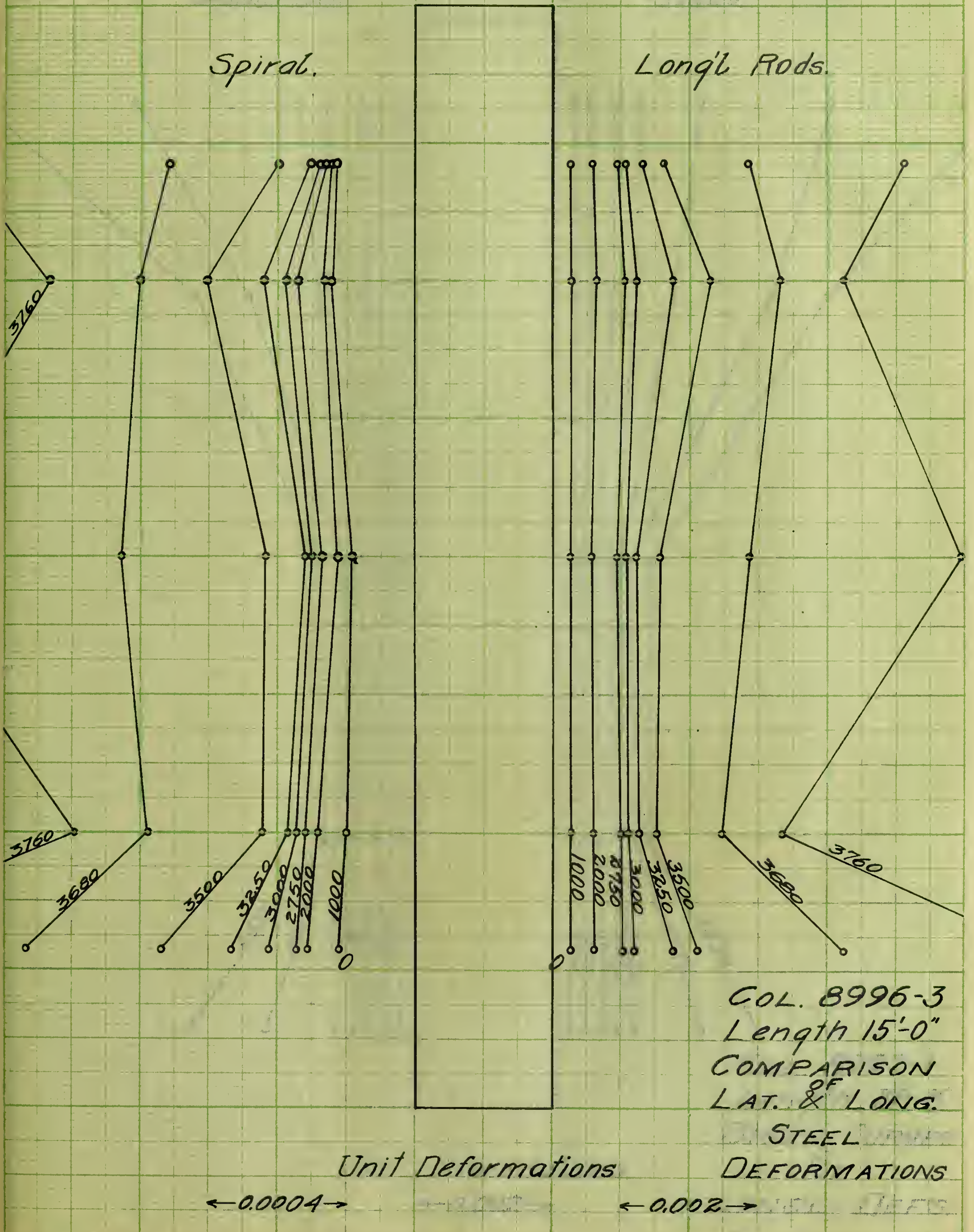
Col. 8996-2
Length 15'-0"
Dist'n Curves
for
Long'l Def's.



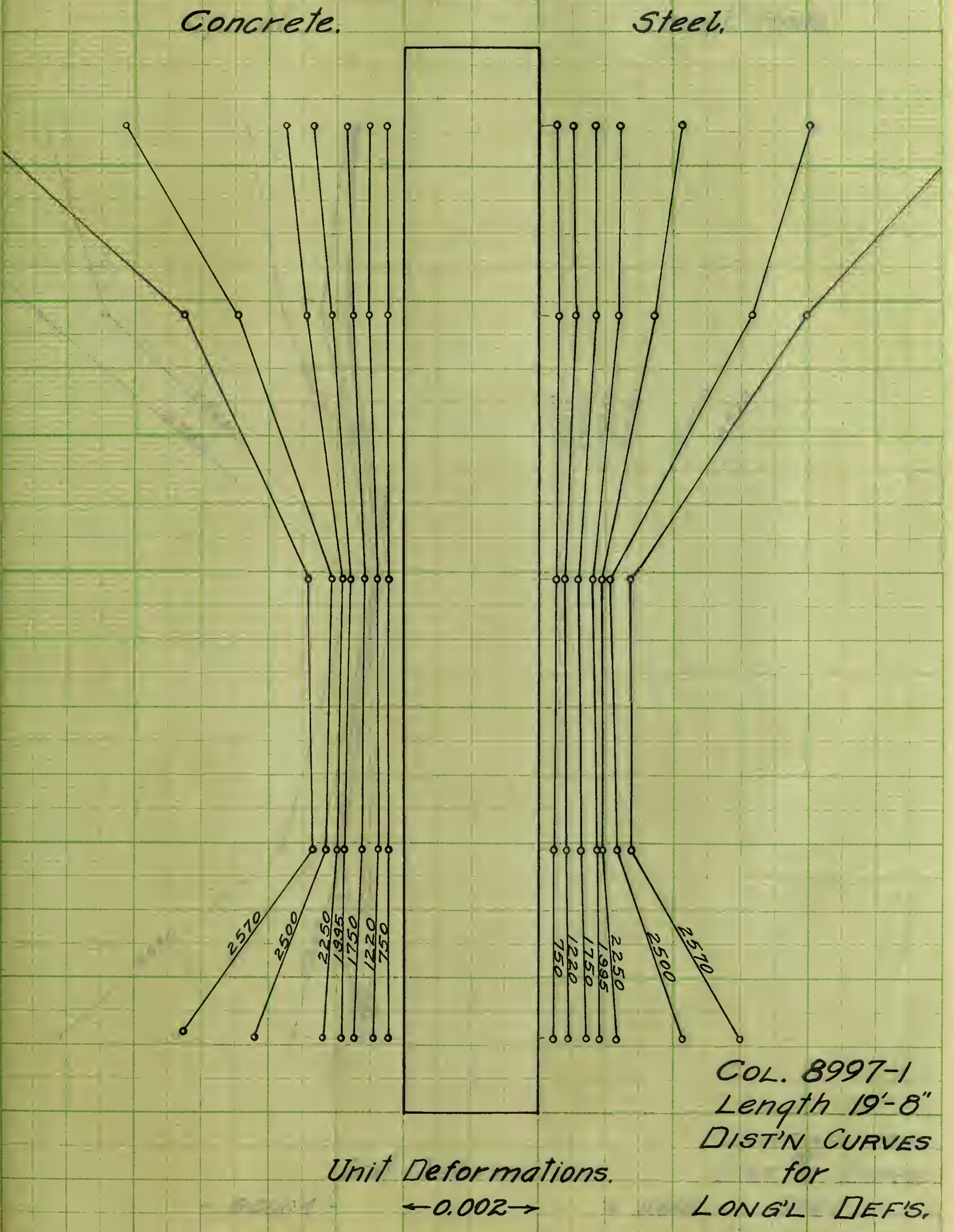
Col. 8996-2
Length 15'-0"
Comparison
of
Lat. & Long.
Steel
Deformations



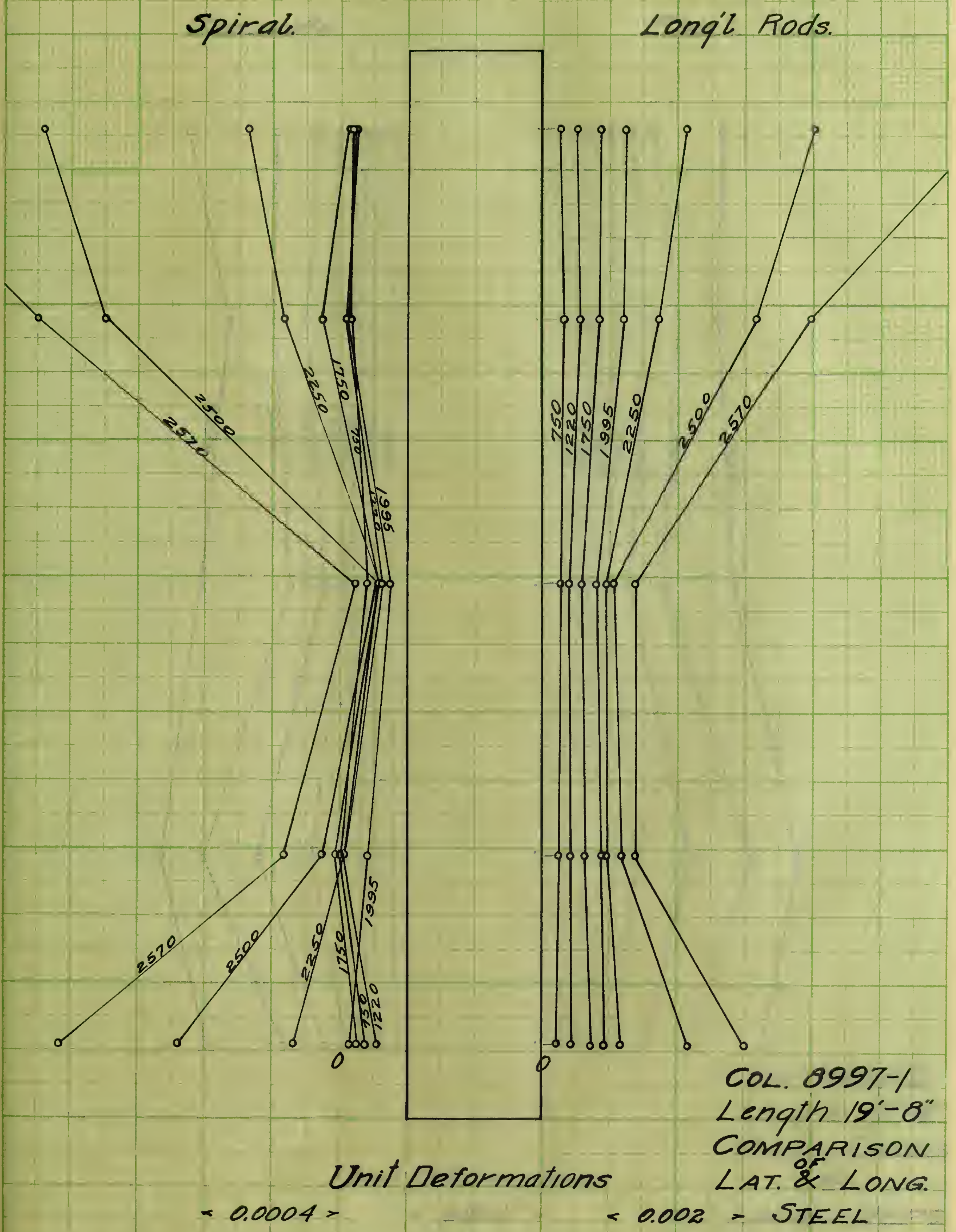
Col. 8996-3
Length 15'-0"
Dist'n Curves
for
Long'l Def's.



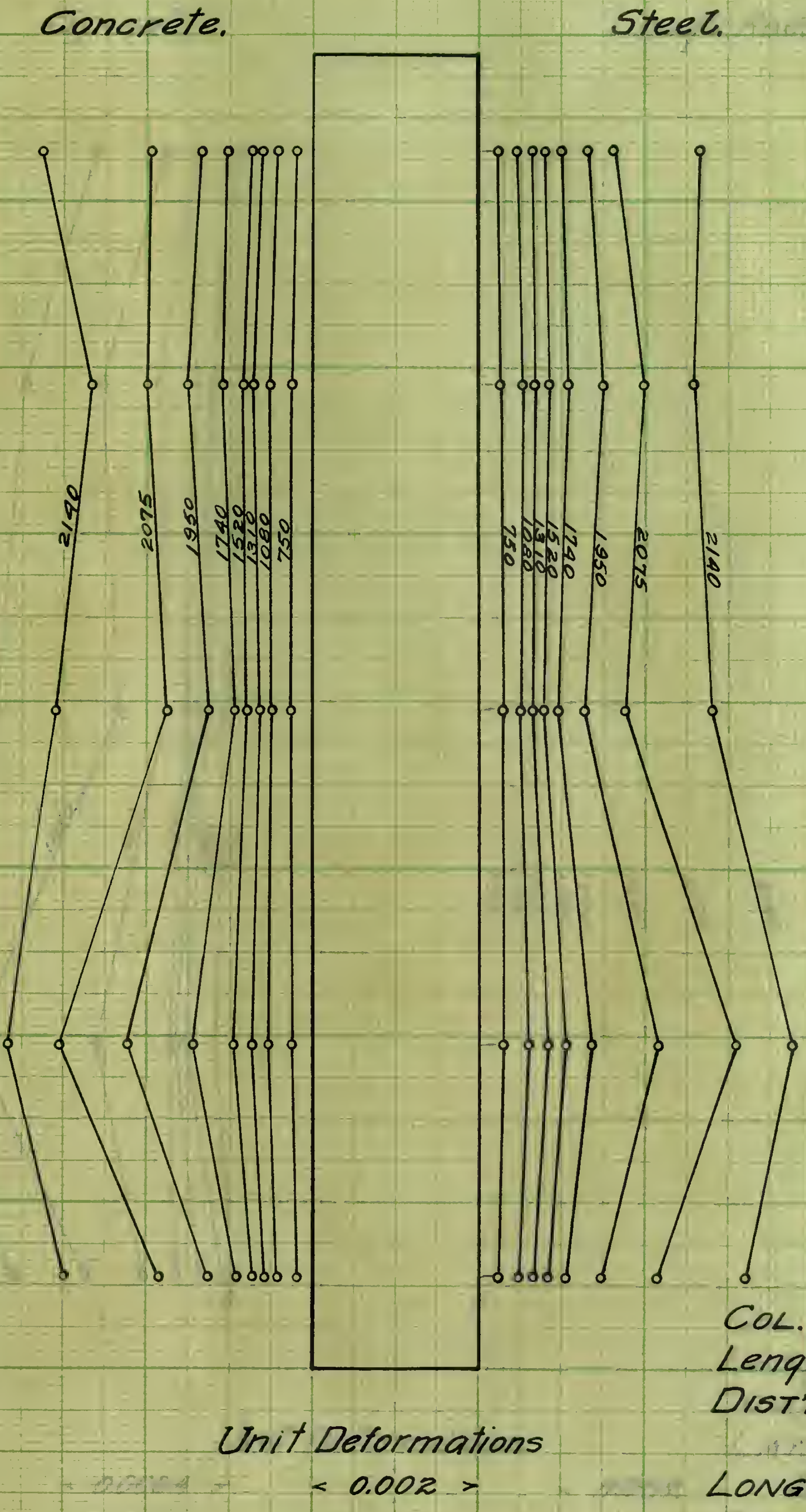
Col. 8996-3
Length 15'-0"
Comparison
of
Lat. & Long.
Steel
Deformations



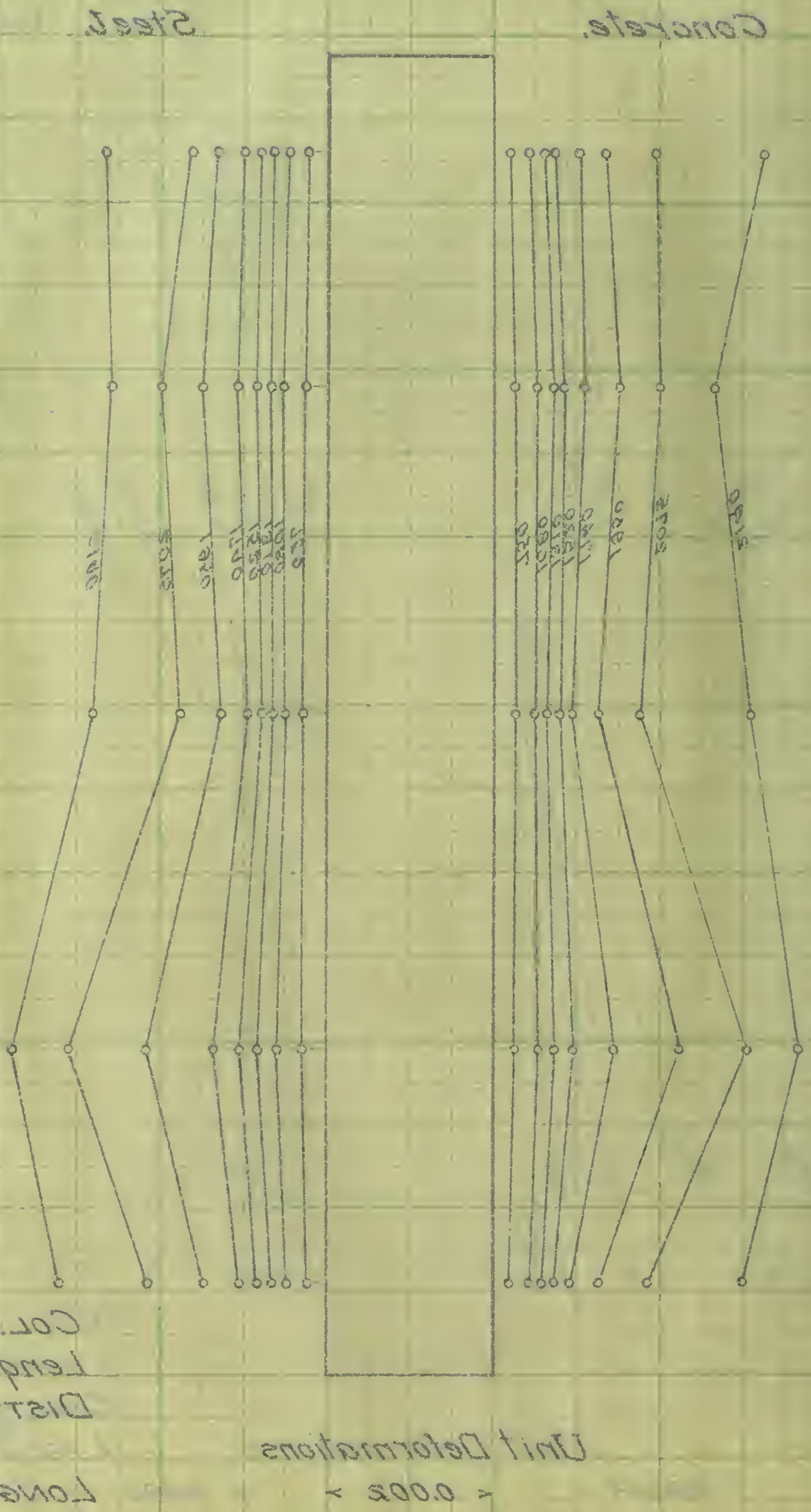
Col. 8997-1
Length 19'-8"
Dist'n Curves
for
Long'l Def's.



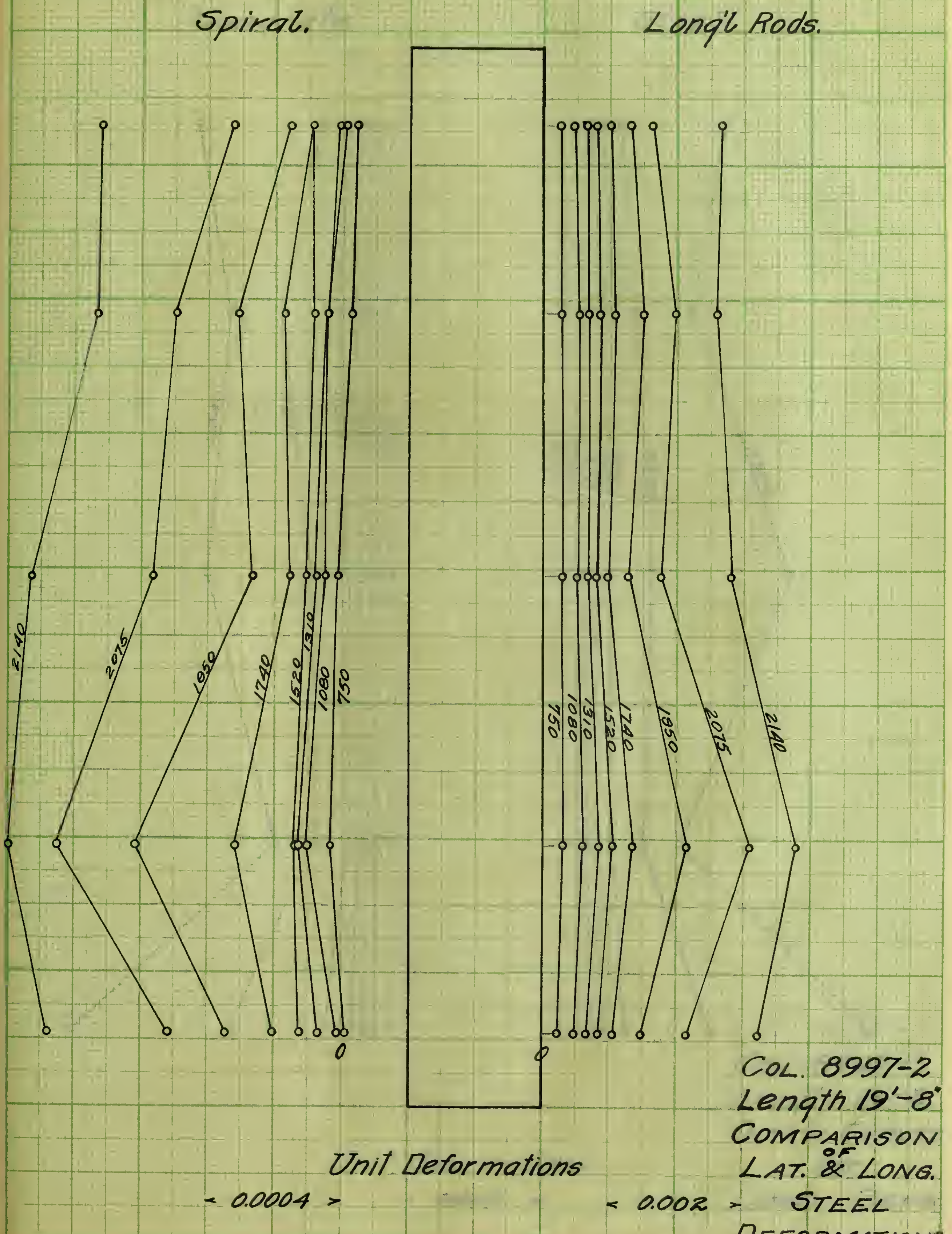
COL. 8997-1
Length 19'-8"
COMPARISON
of
LAT. & LONG.
STEEL
DEFORMATIONS



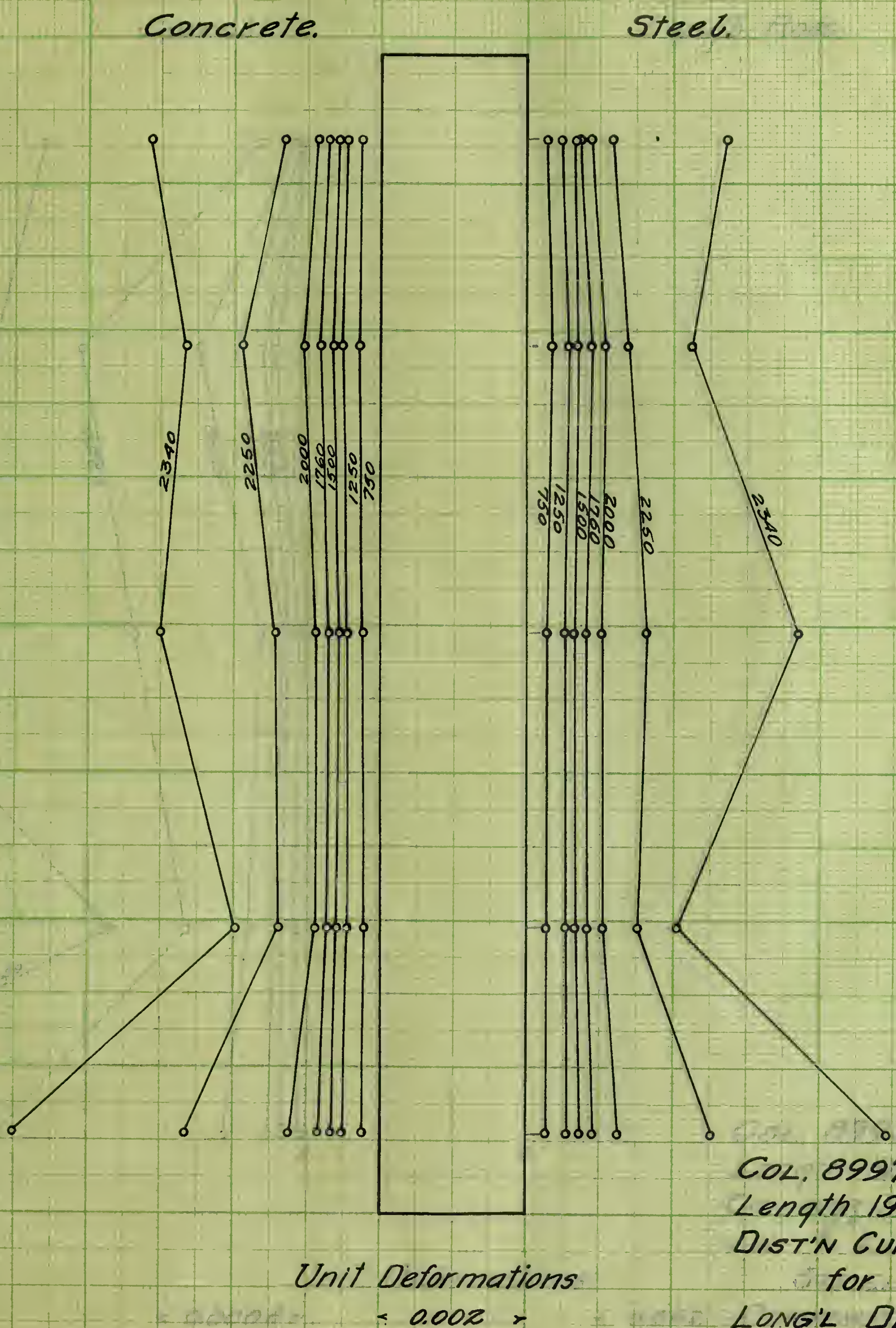
Col. 8997-2
Length 19'-8"
Dist'n Curves
for
Long'l Def's.



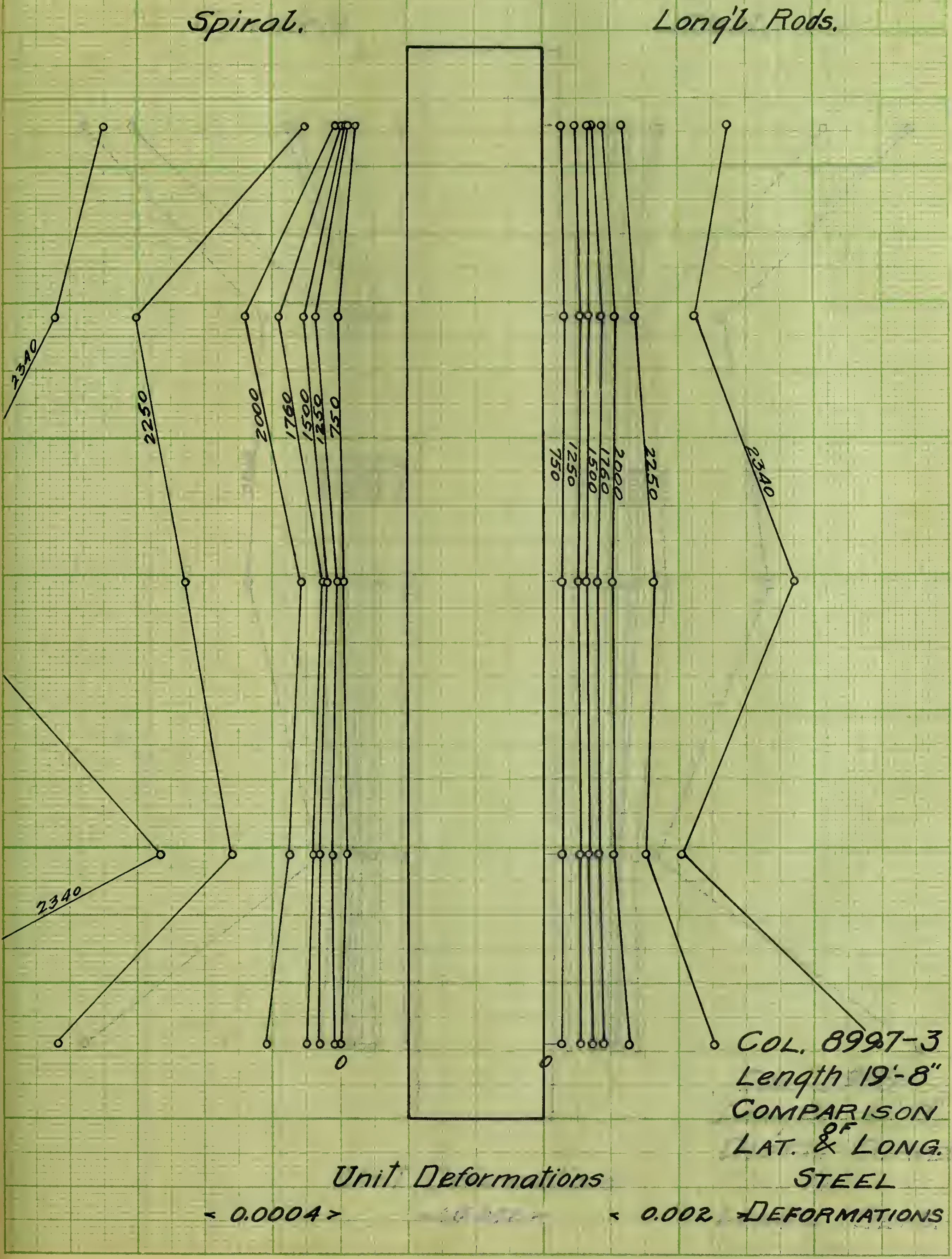
Col. 8997-2
Length 19'-8"
Dist'n Curves
for
Longt. Def's.

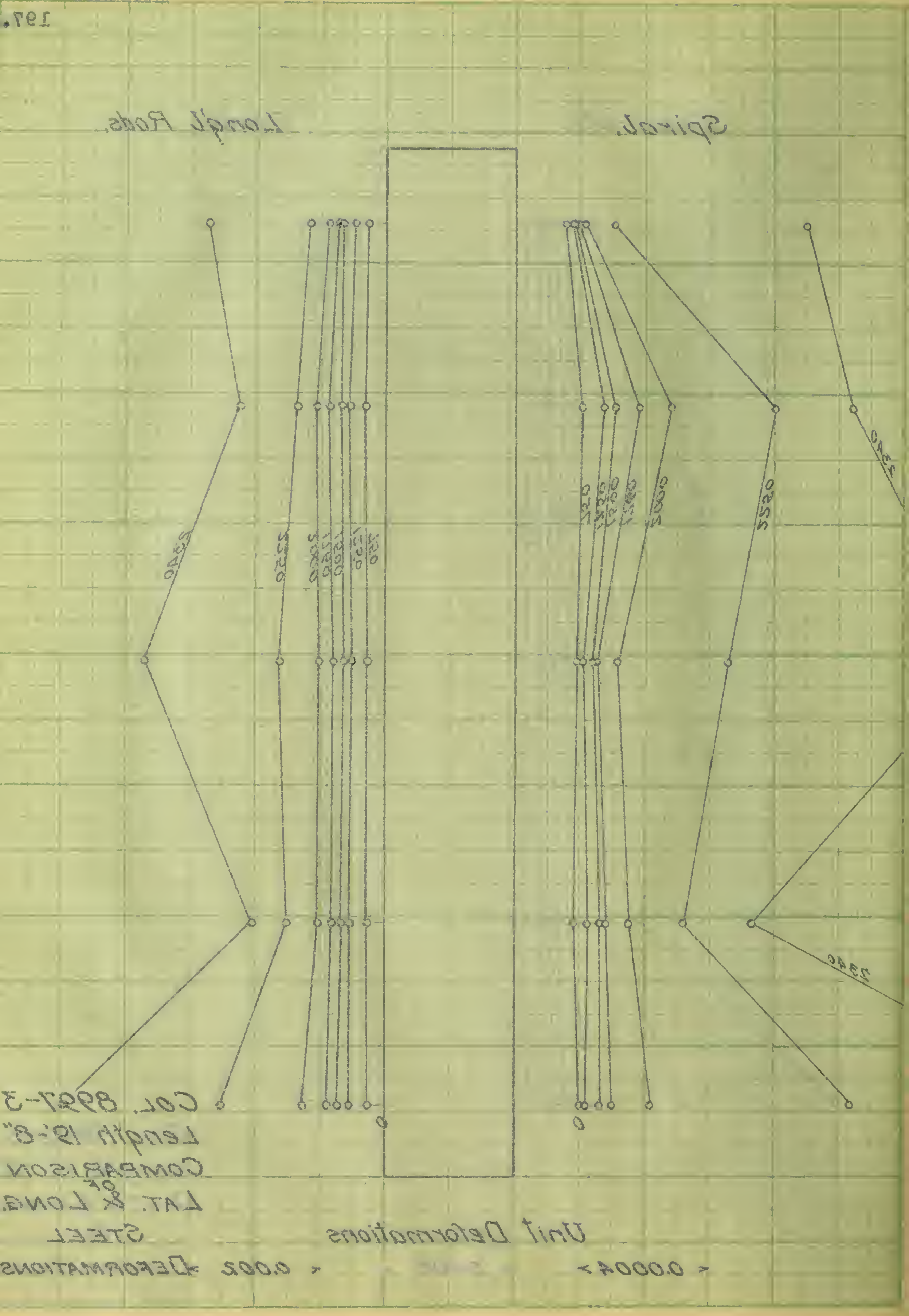


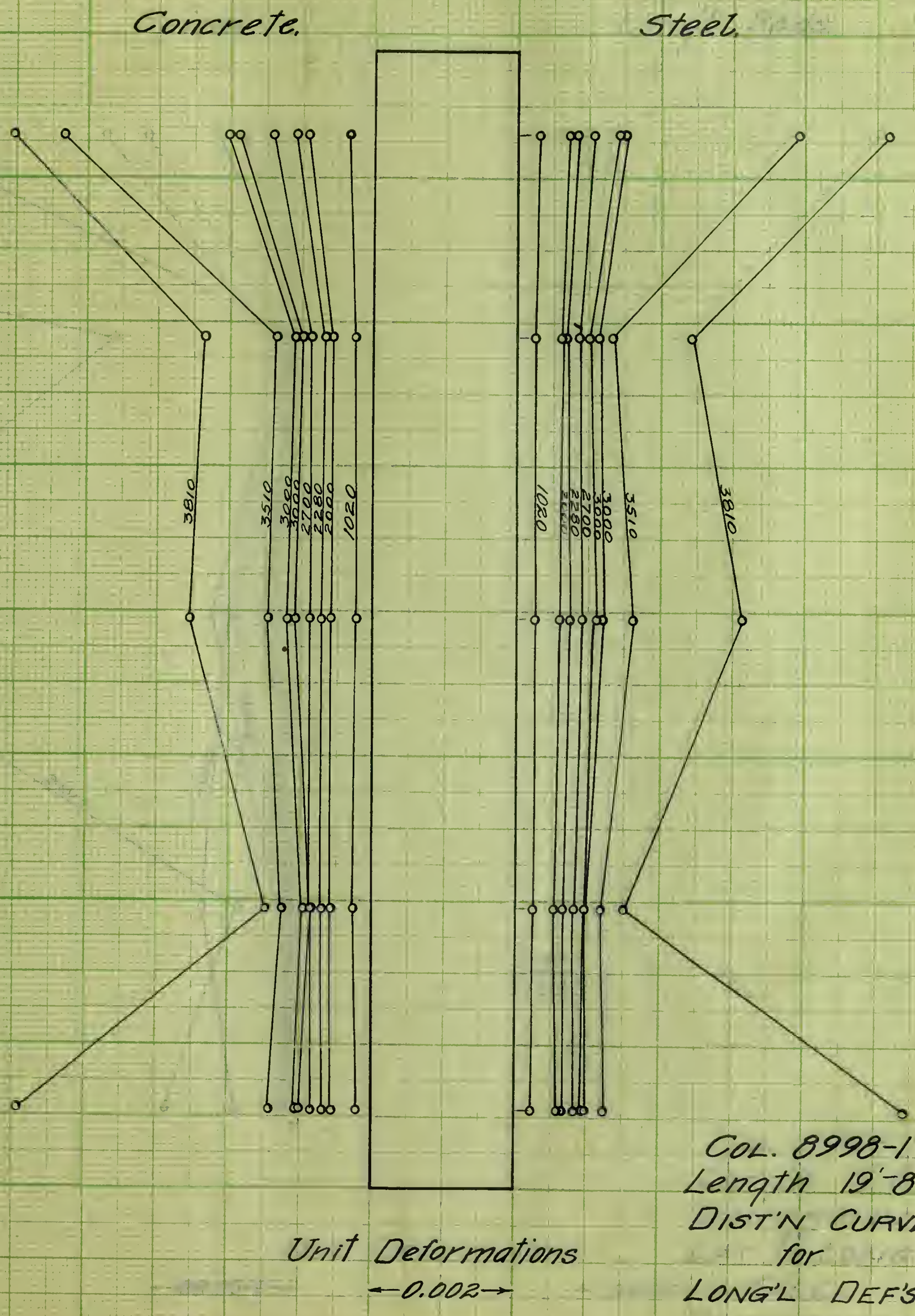
Col. 8997-2
Length 19'-8"
Comparison
of
Lat. & Long.
Steel
Deformations



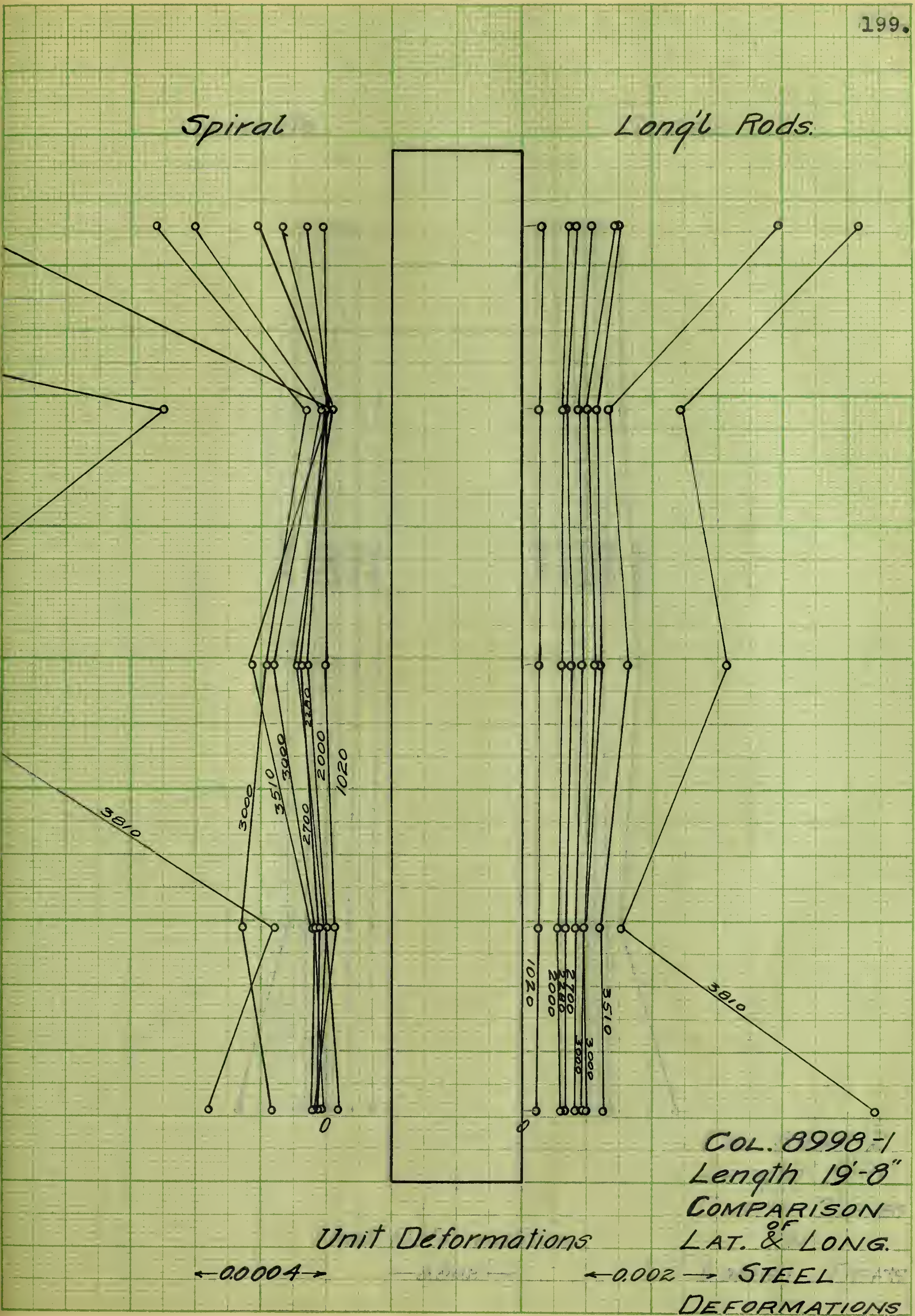
Col. 8997-3
Length 19'-8"
Dist'n Curves
for
Long'l Def's.


Spiral.
Long'l Rods.
2340
2250
2000
1760
1500
1250
750
750
1250
1500
1760
2000
2250
2340
2340
0
0
Col. 8997-3
Length 19'-8"
Comparison of Lat. & Long. Steel
Unit Deformations
< 0.0004 >
< 0.002 Deformations

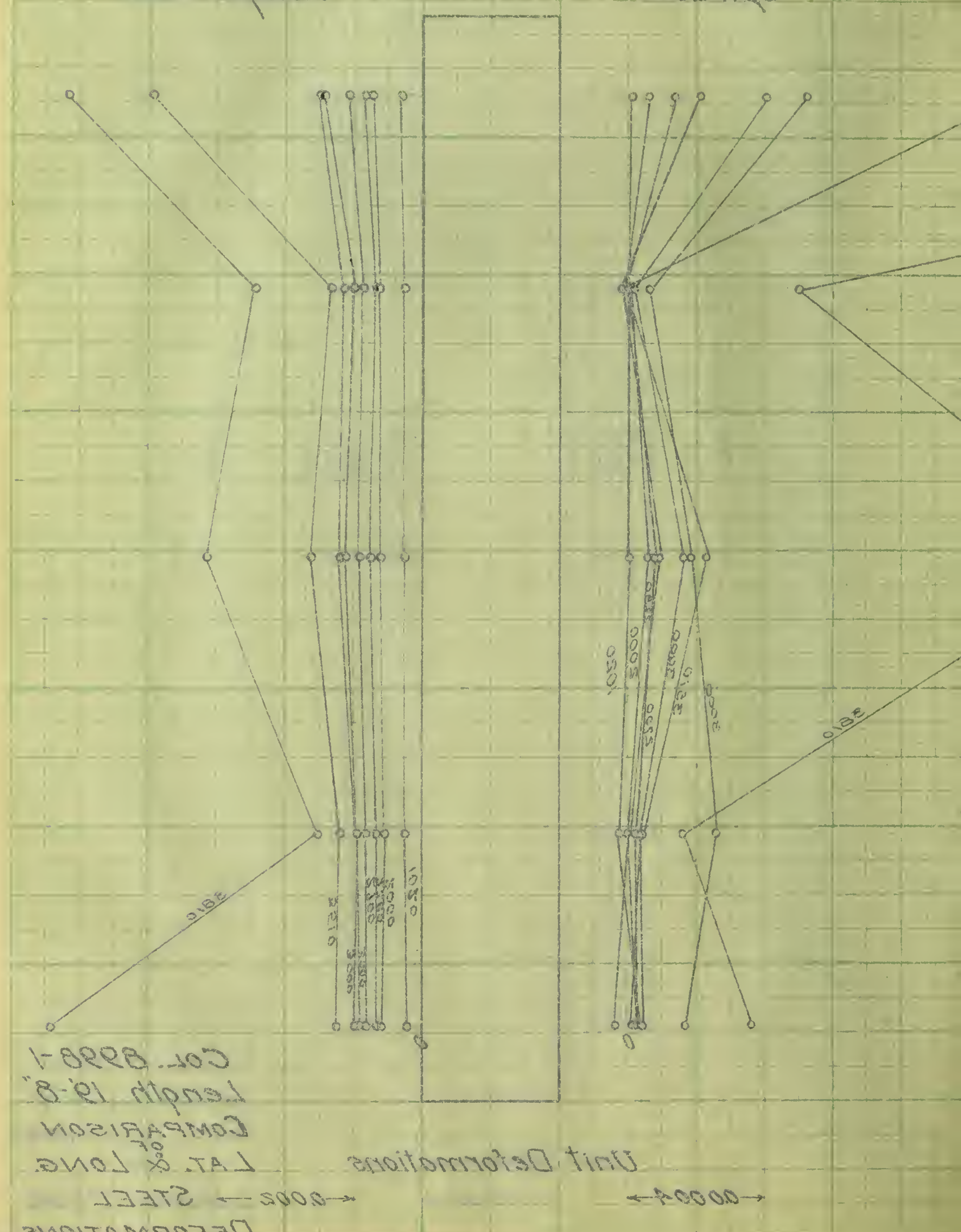

Long'l Rods.
Spiral.
2340
2250
2000
1750
1500
2000
1750
1500
2250
2340
2340
0
0
Col. 8997-3
Length 12'-8"
COMPARISON
of
LAT. & LONG.
STEEL
Unit Deformations
DEFORMATIONS = 0.002
0.0004



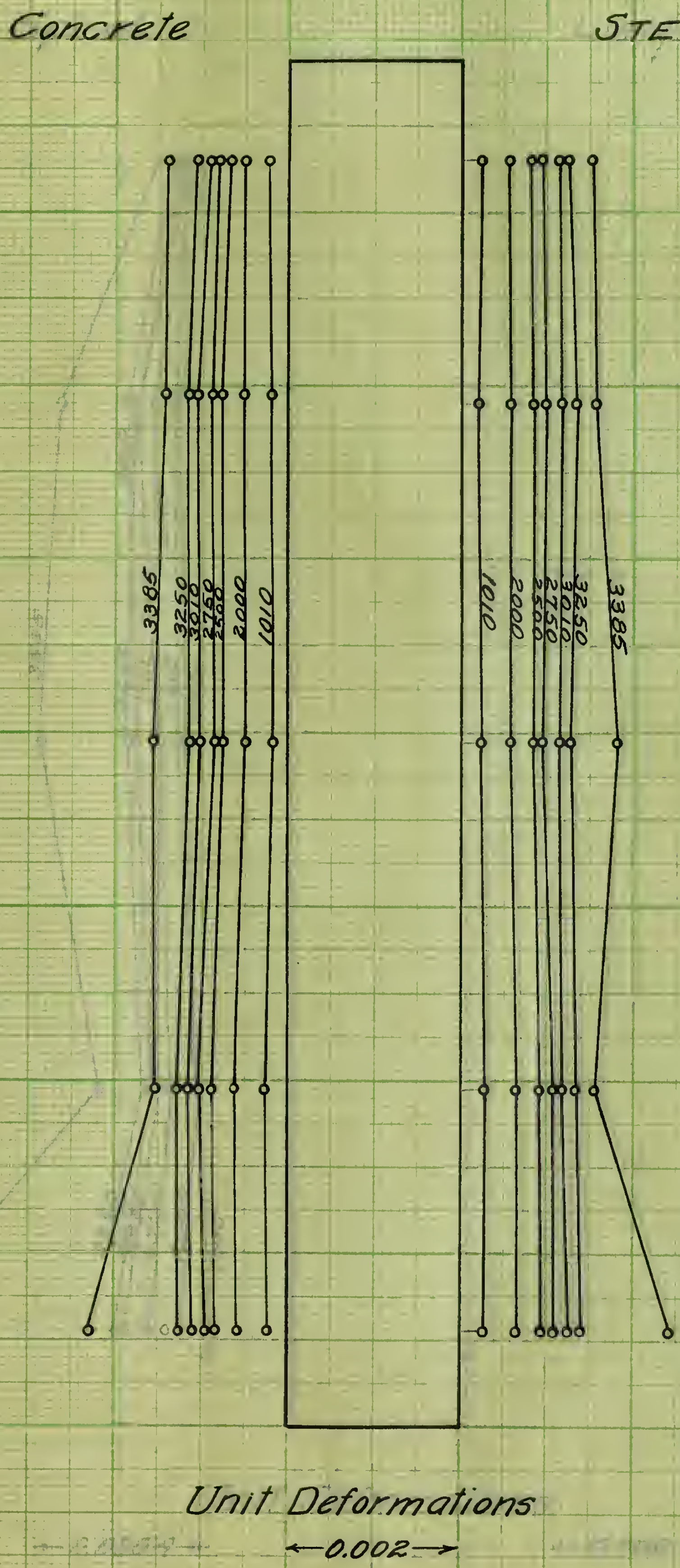
Col. 8998-1
Length 19'-8"
DIST'N CURVES
for
LONG'L DEF'S.



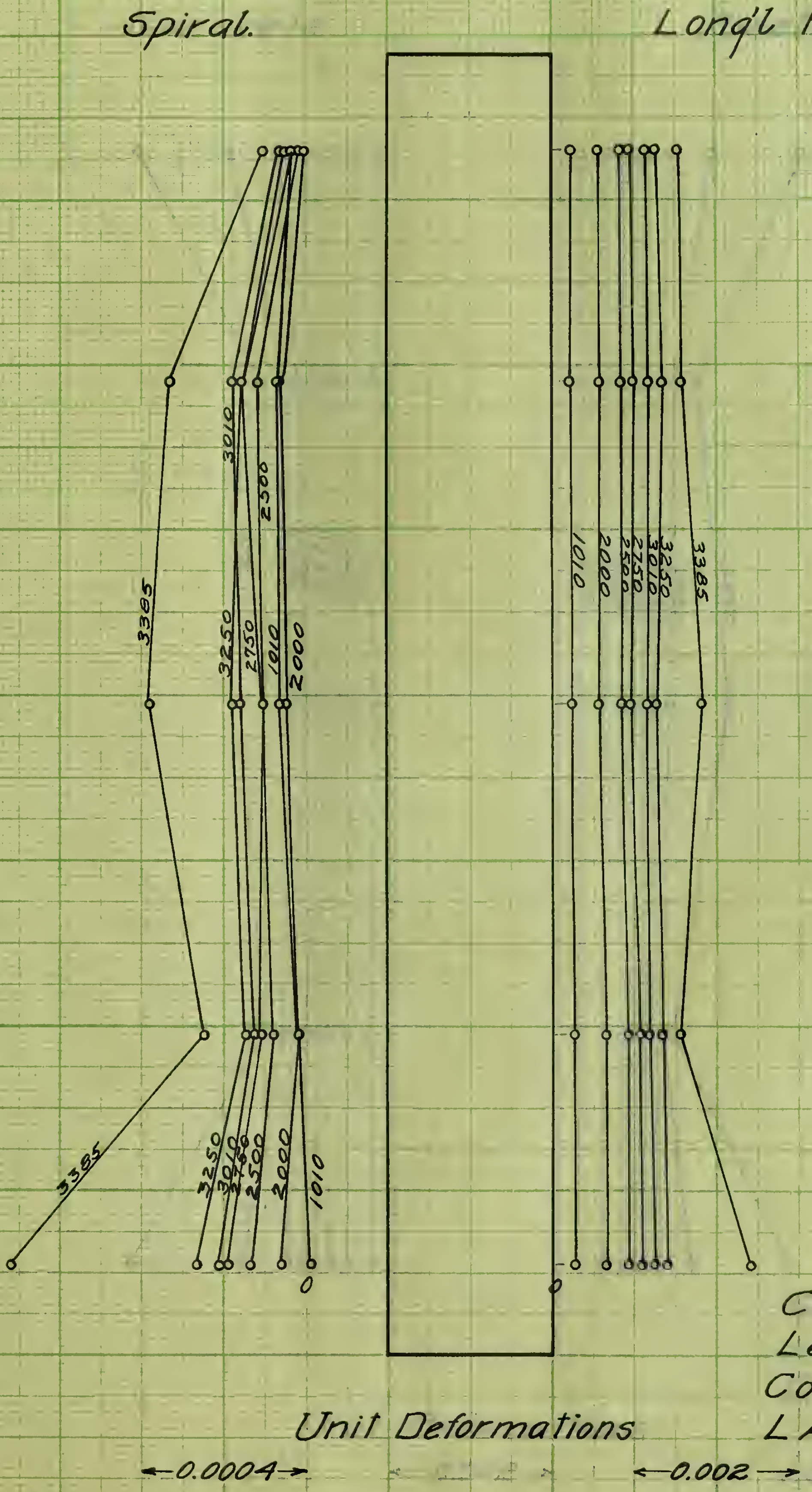
Col. 8998-1
Length 19'-8"
Comparison of Lat. & Long. Steel Deformations



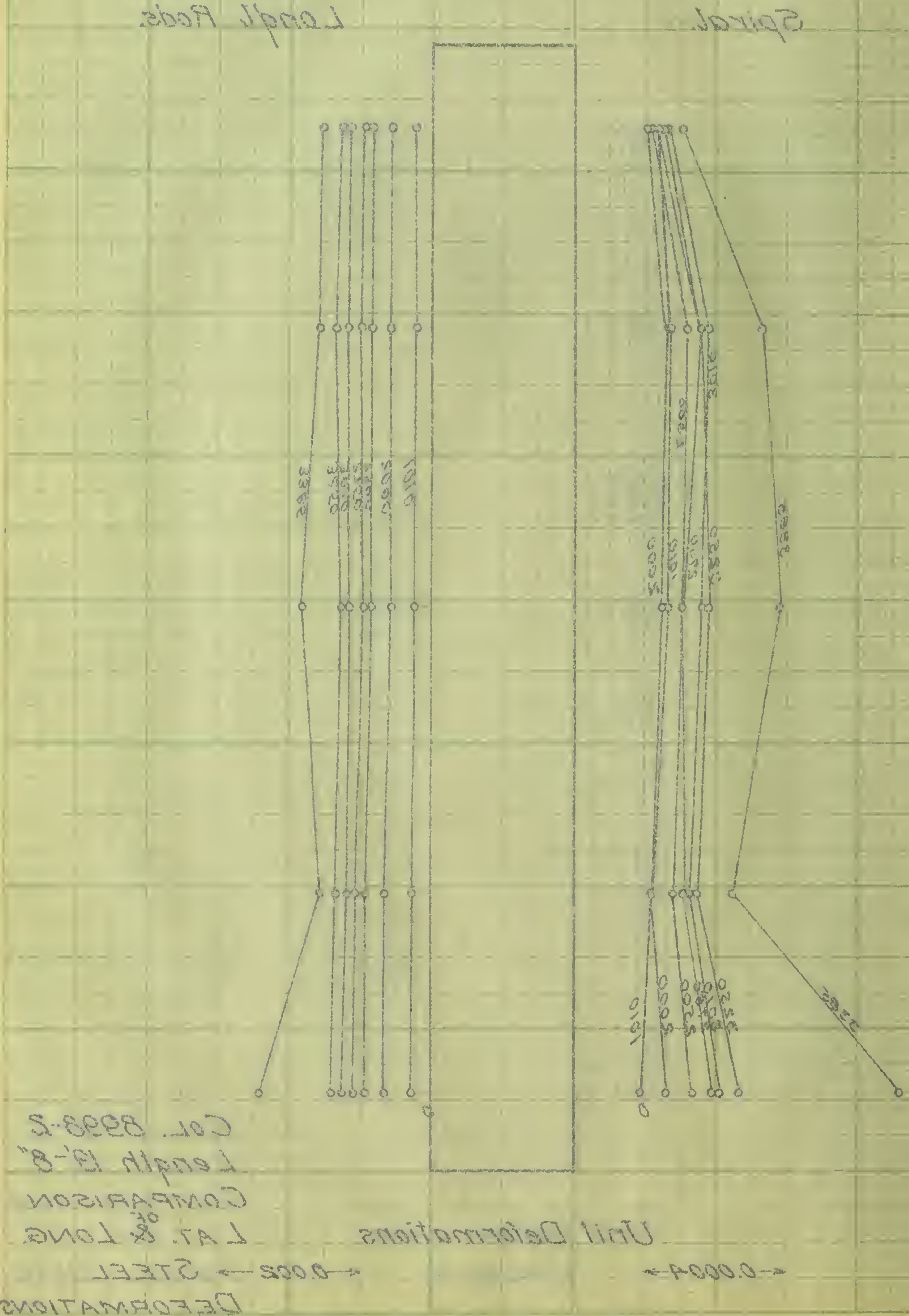
Col. 8998-1
Length 19'-8"
COMPARISON
of
LAT. & LONG.
STEEL
DEFORMATIONS

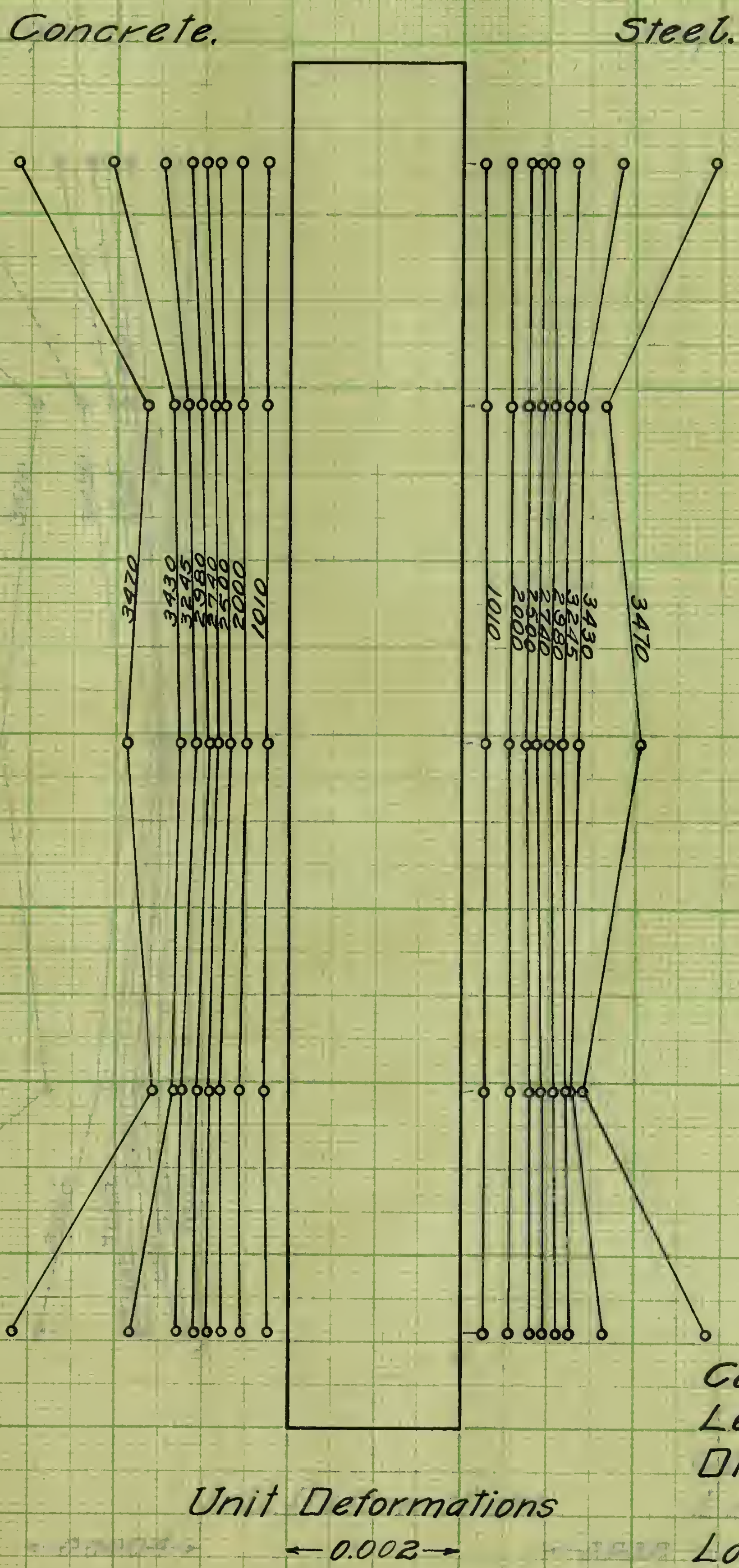


Col. 8998-2
Length 19'-8"
Dist'n Curves
for
Long'l Def's.

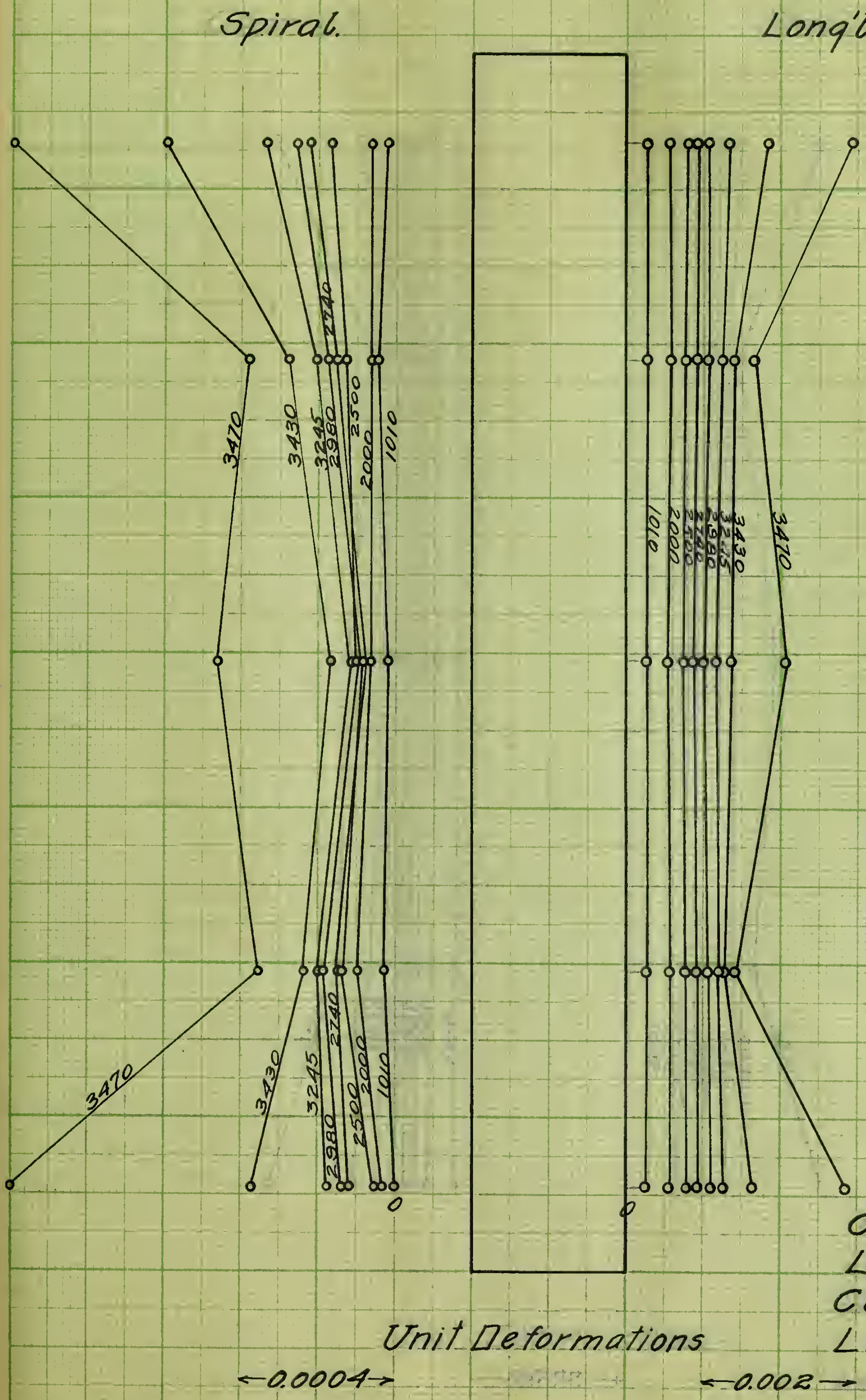


Col. 8998-2
Length 19'-8"
Comparison
of
Lat. & Long.
Steel
Deformations

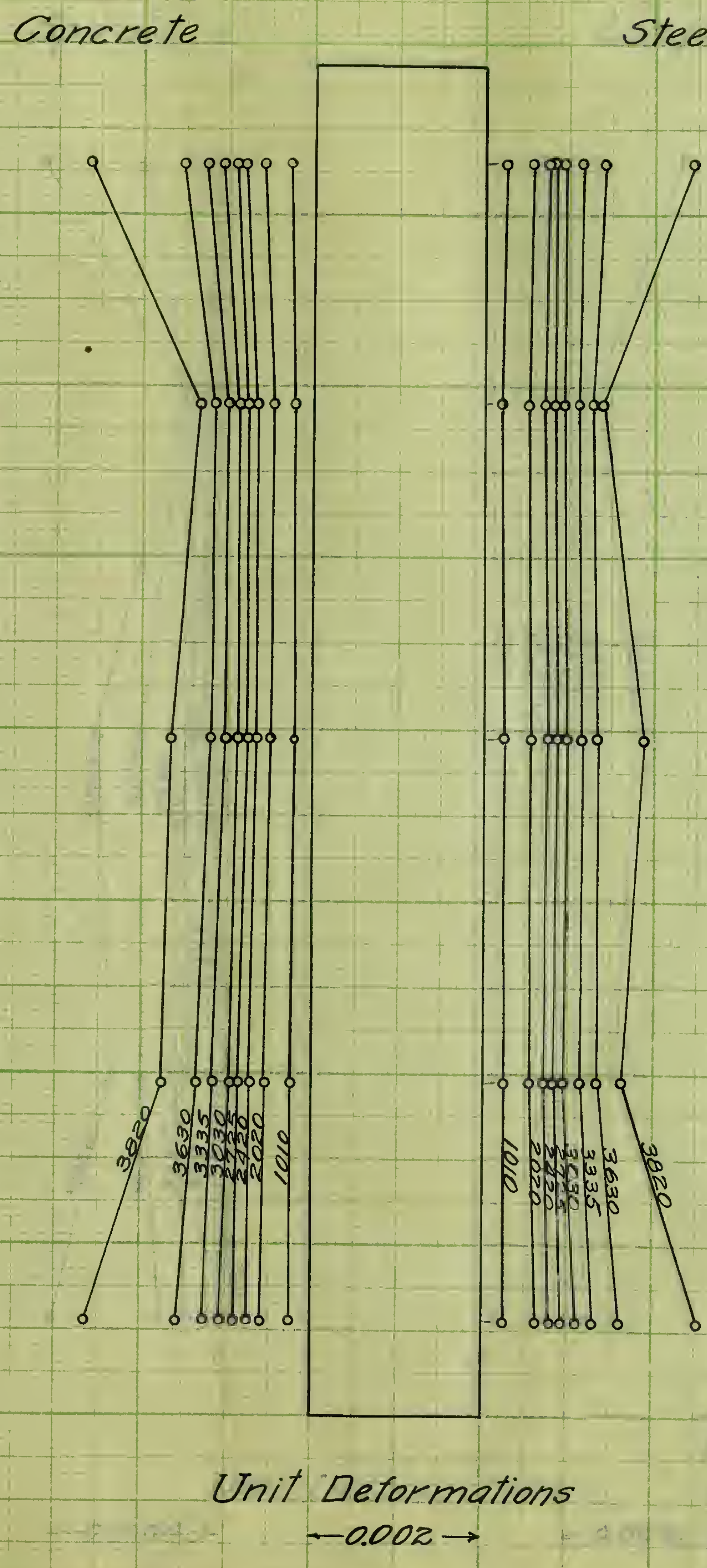




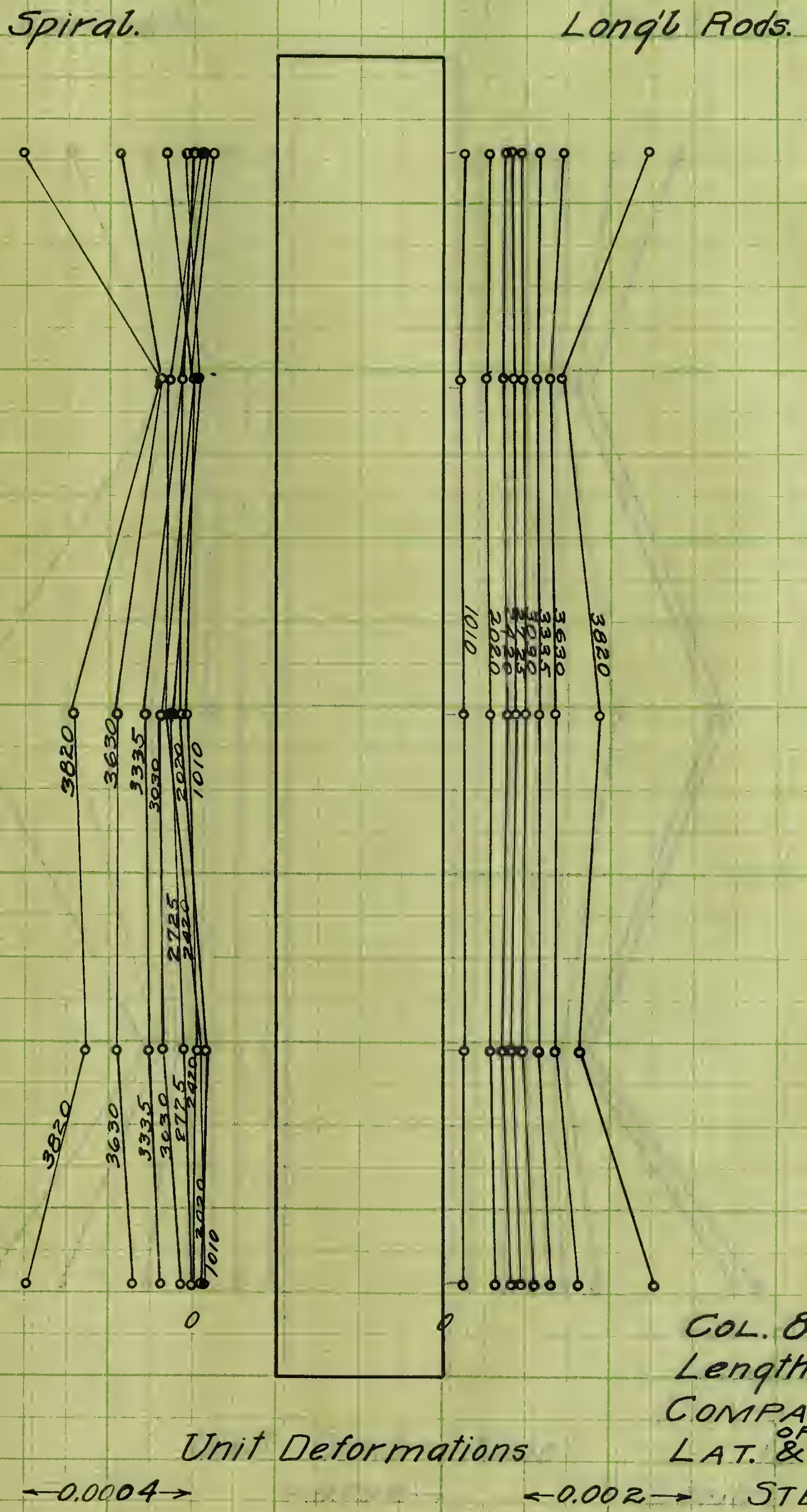
Col. 8998-3
Length 19'-8"
Dist'n Curves
for
Long'l Def's.



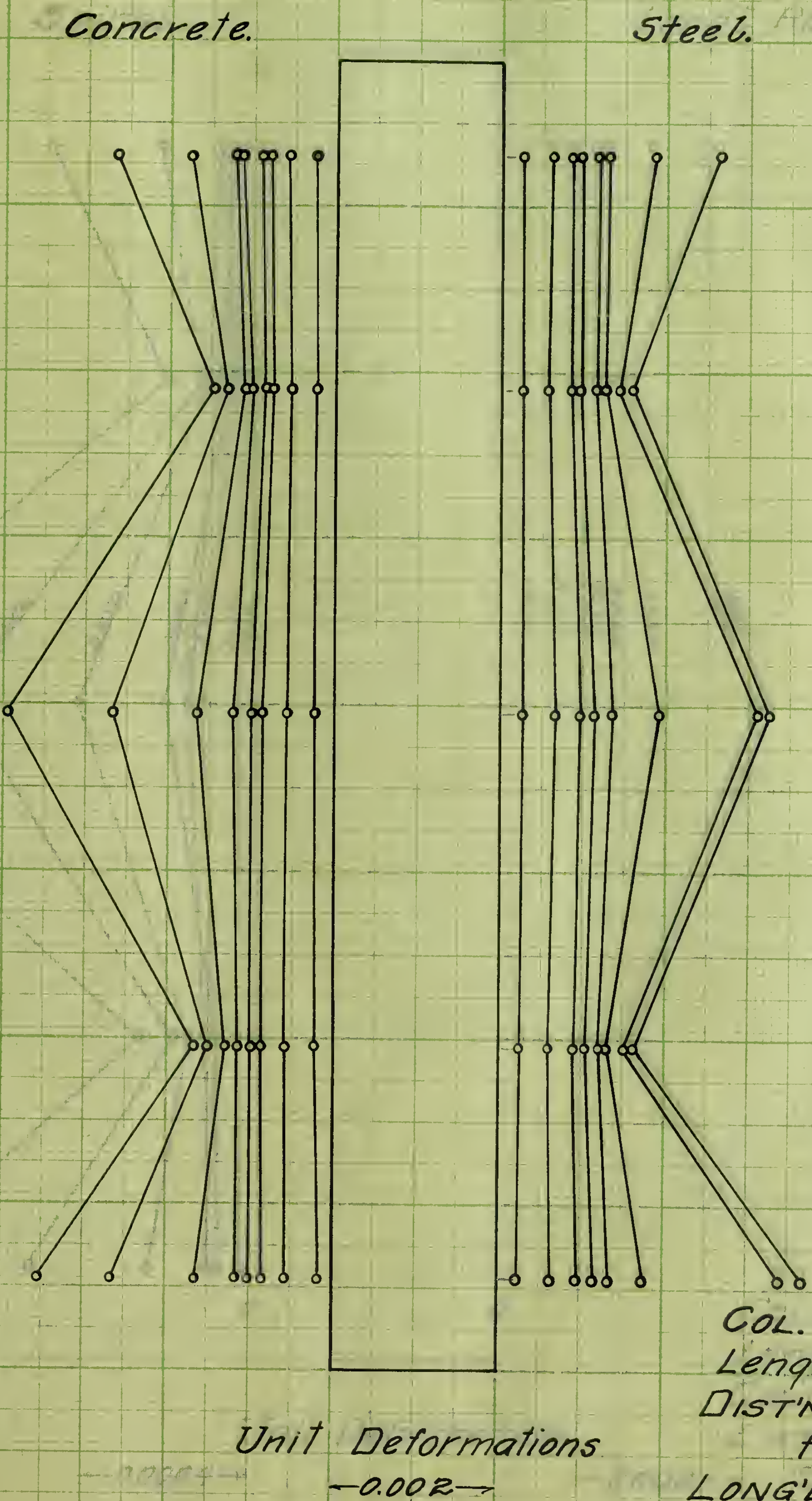
Col. 8998-3
Length 19'-8"
Comparison
of
Lat. & Long.
Steel
Deformations



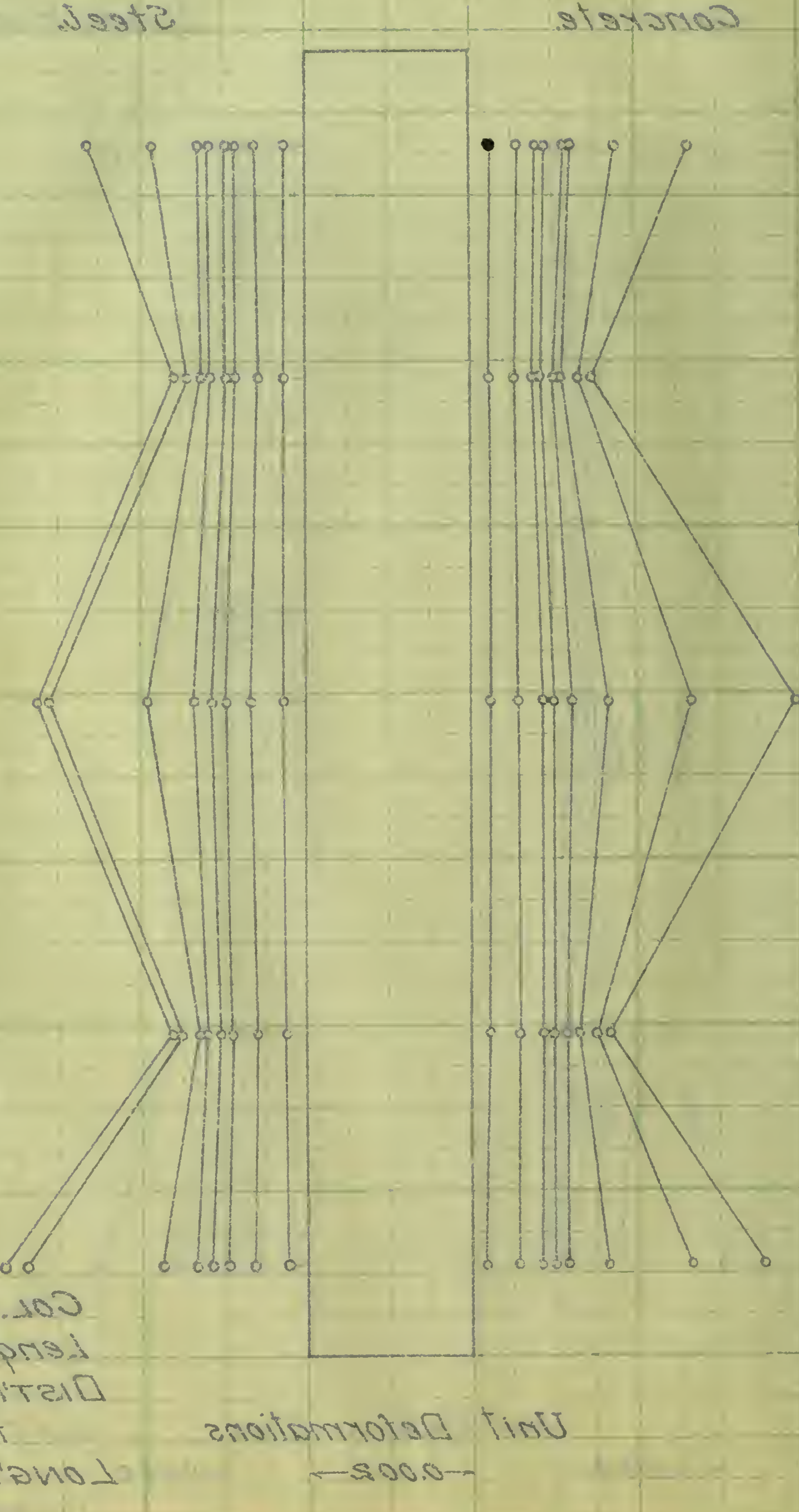
COL. 8999-1
Length 19'-8"
DIST'N CURVES
for
LONG'L DEF'S.



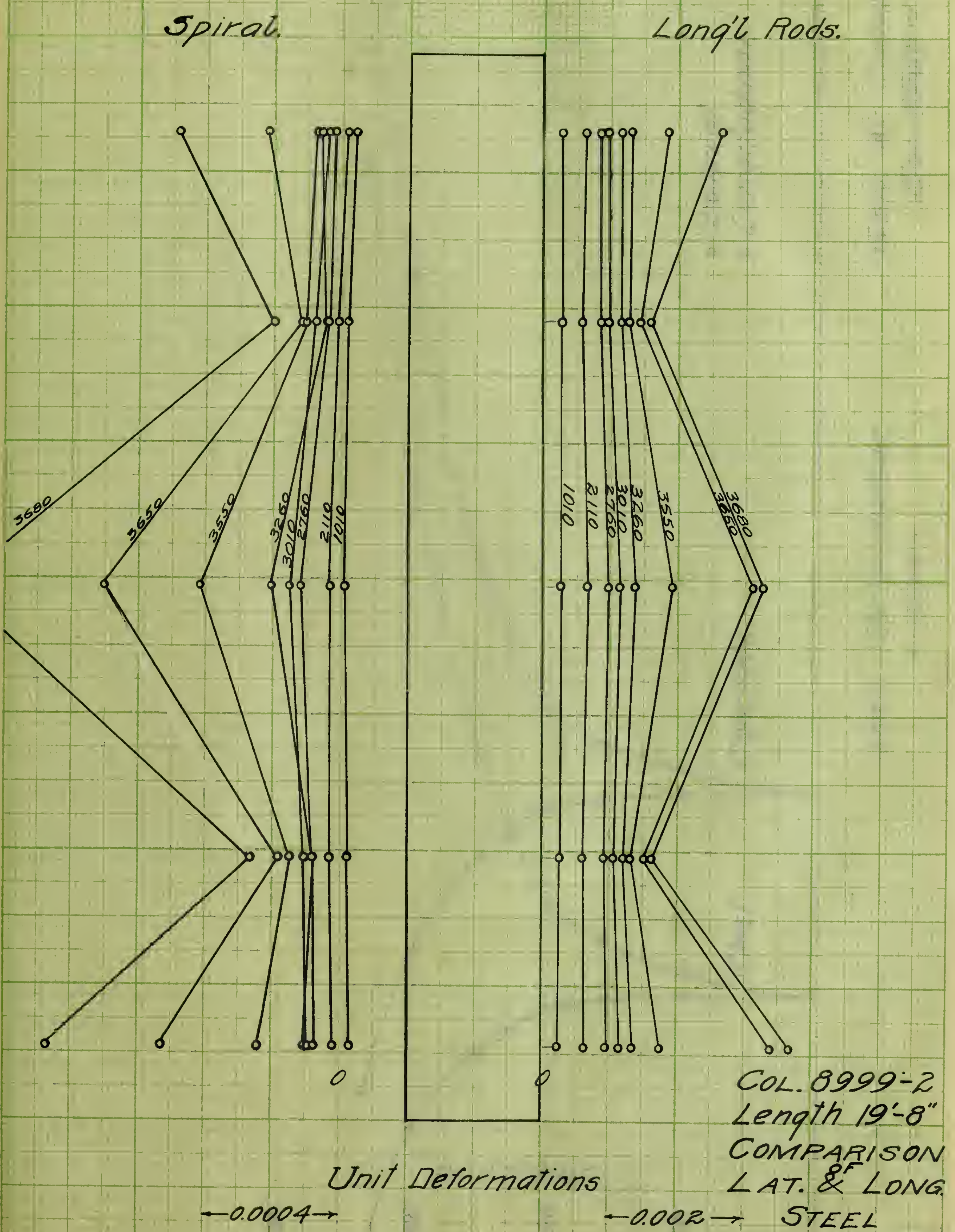
Col. 8999-1
Length 19'-8"
Comparison
of
Lat. & Long.
Steel
Deformations



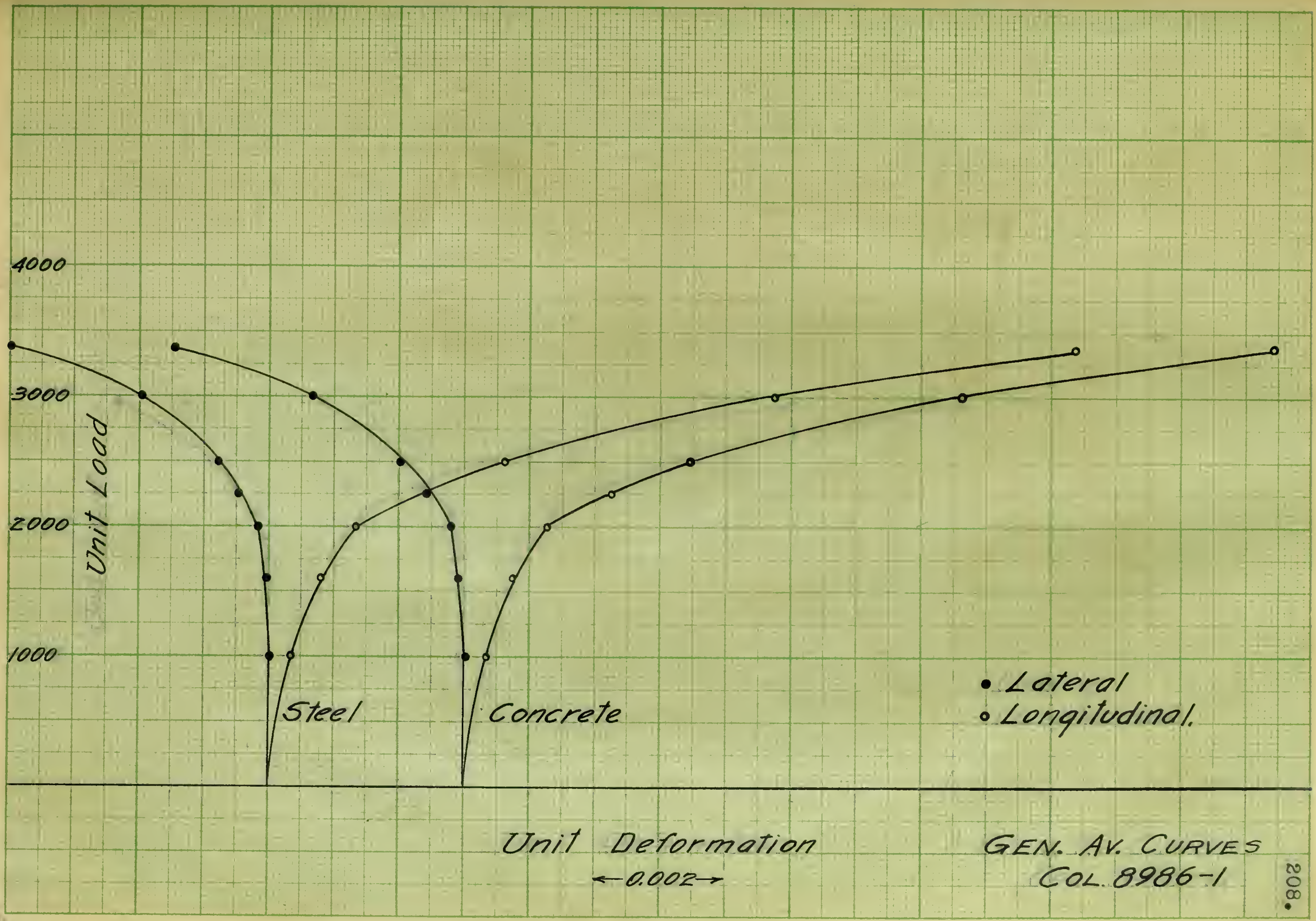
Col. 8999-2
Length 19'-8"
Dist'n Curves
for
Long'l Def's.

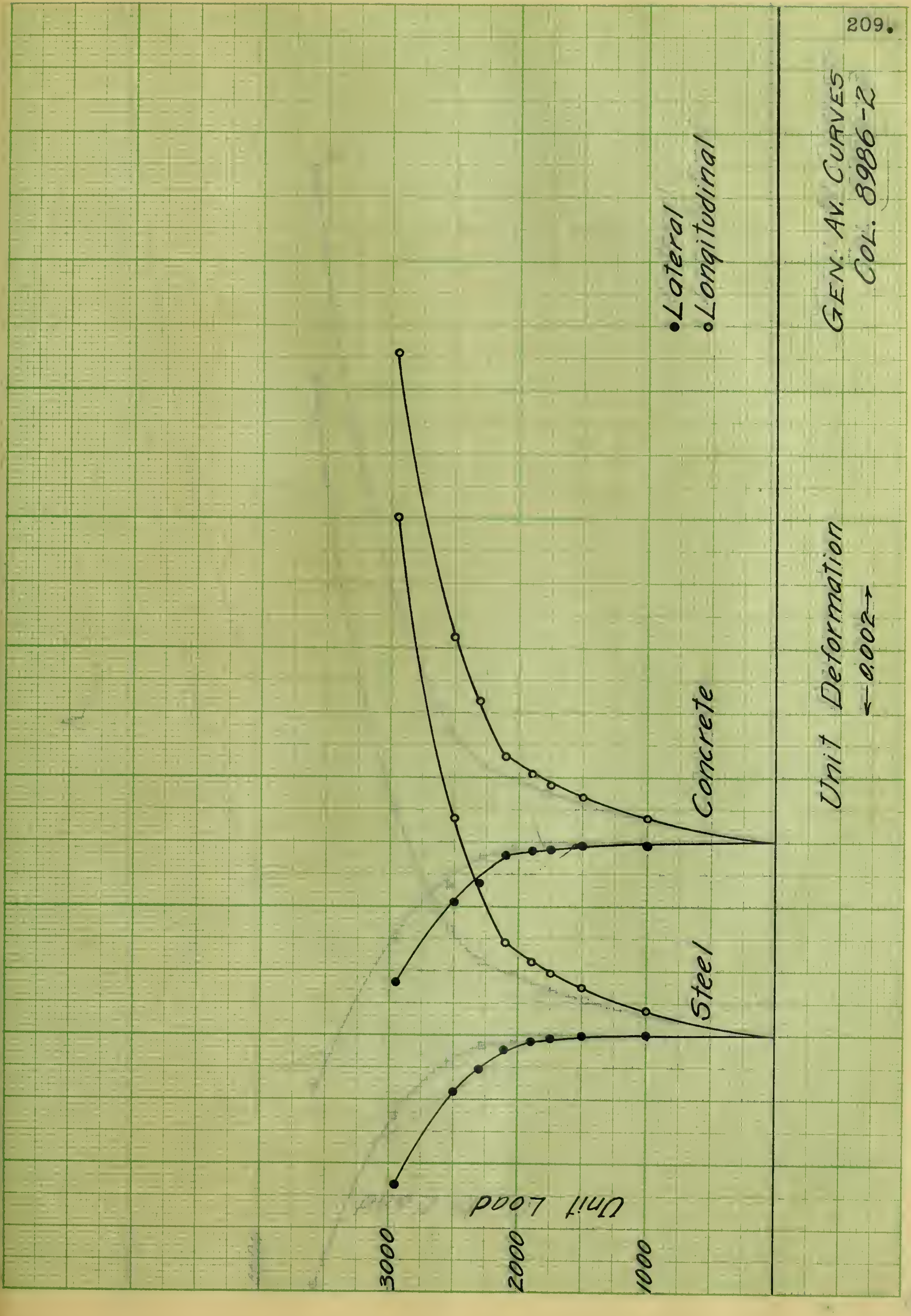


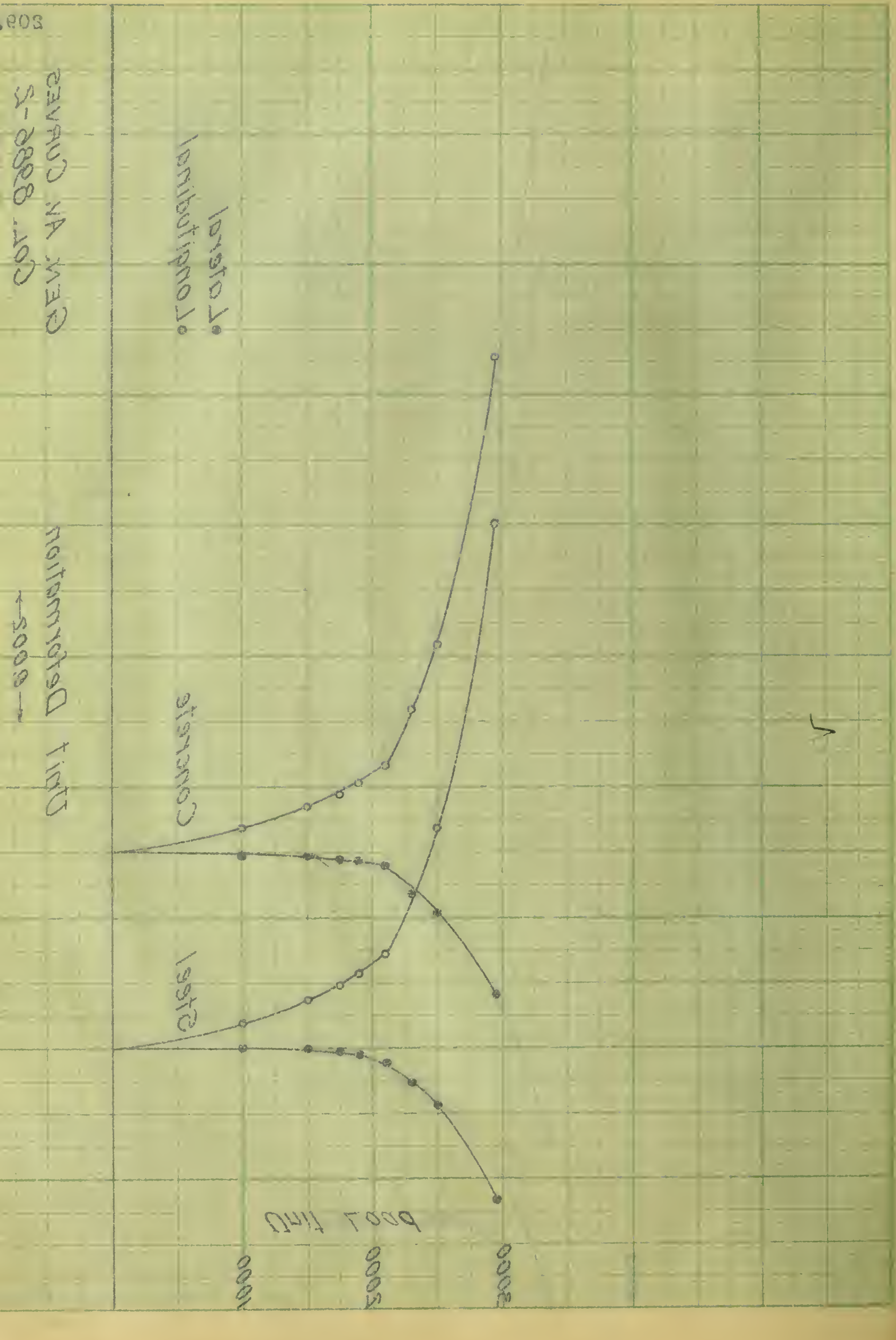
Col. 8999-2
Length 19'-8"
Distn Curves
for
Long'l Def's.

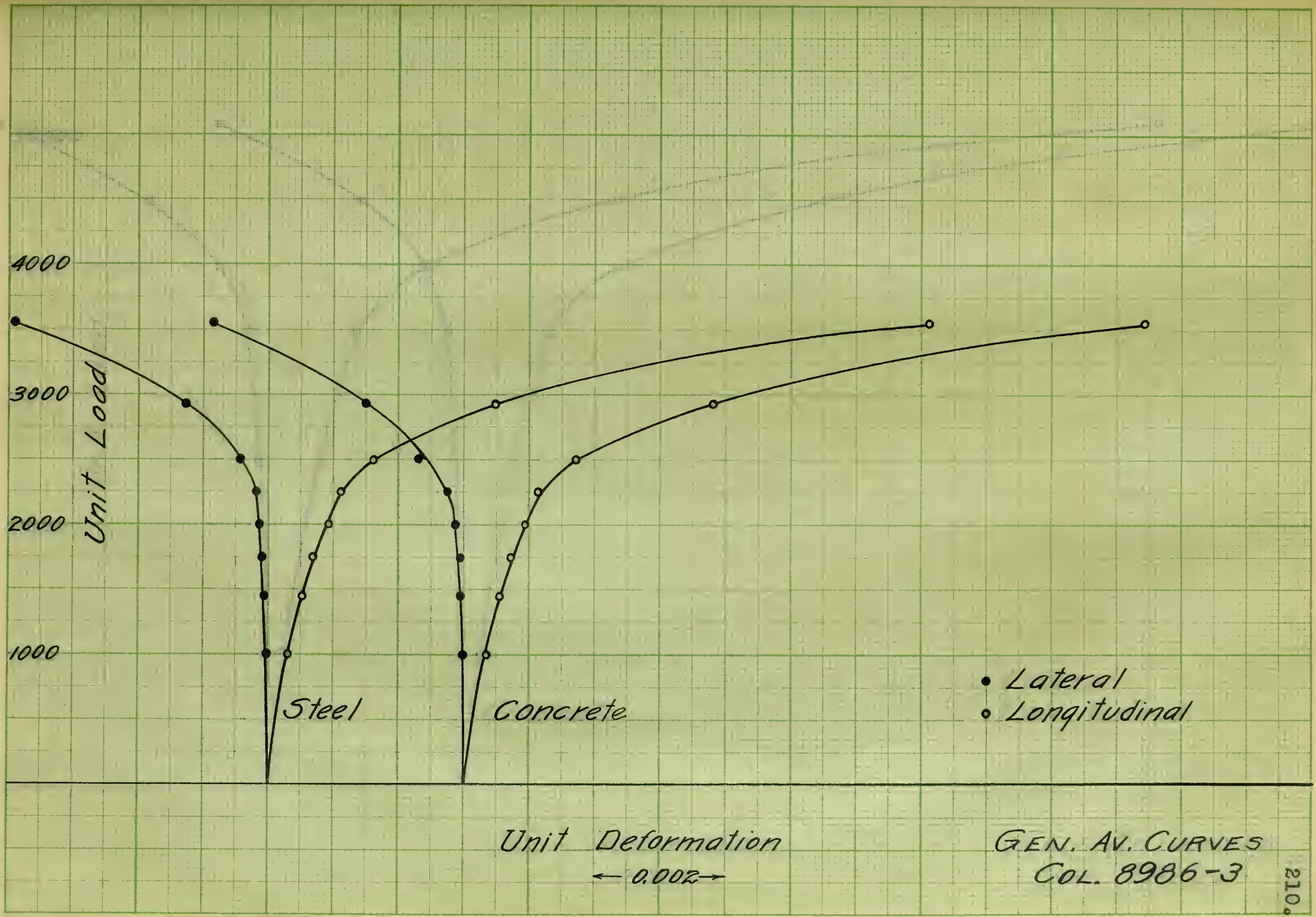


Col. 8999-2
Length 19'-8"
Comparison
of
Lat. & Long.
Steel
Deformations

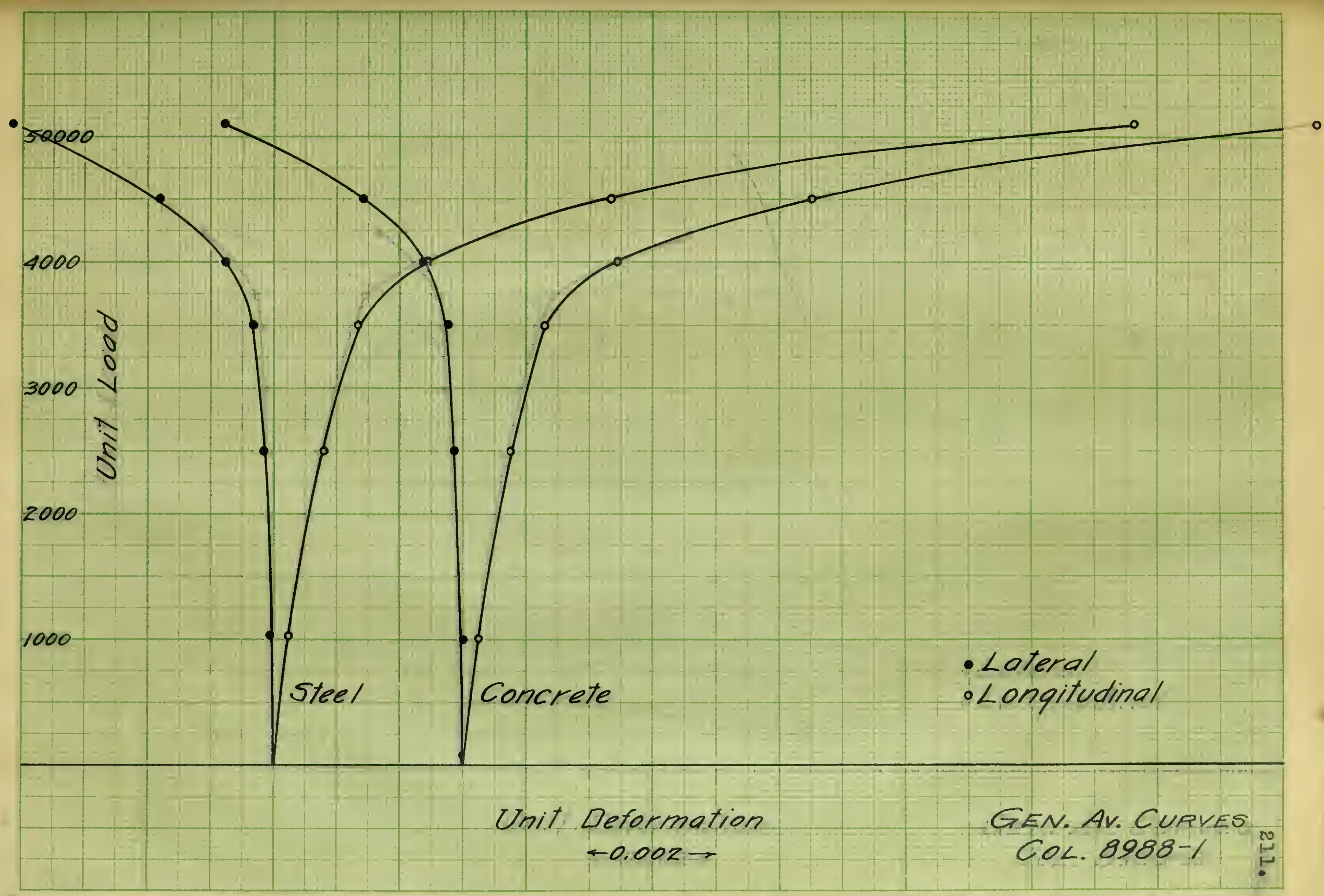

4000
3000
2000
1000
Unit Load
Steel
Concrete
● Lateral
○ Longitudinal.
Unit Deformation
← 0.002 →
GEN. AV. CURVES
COL. 8986-1


•Lateral
∘Longitudinal
GEN. AV. CURVES
COL. 8986-2
Concrete
Steel
Unit Deformation
←0.002→
Unit Load
3000
2000
1000

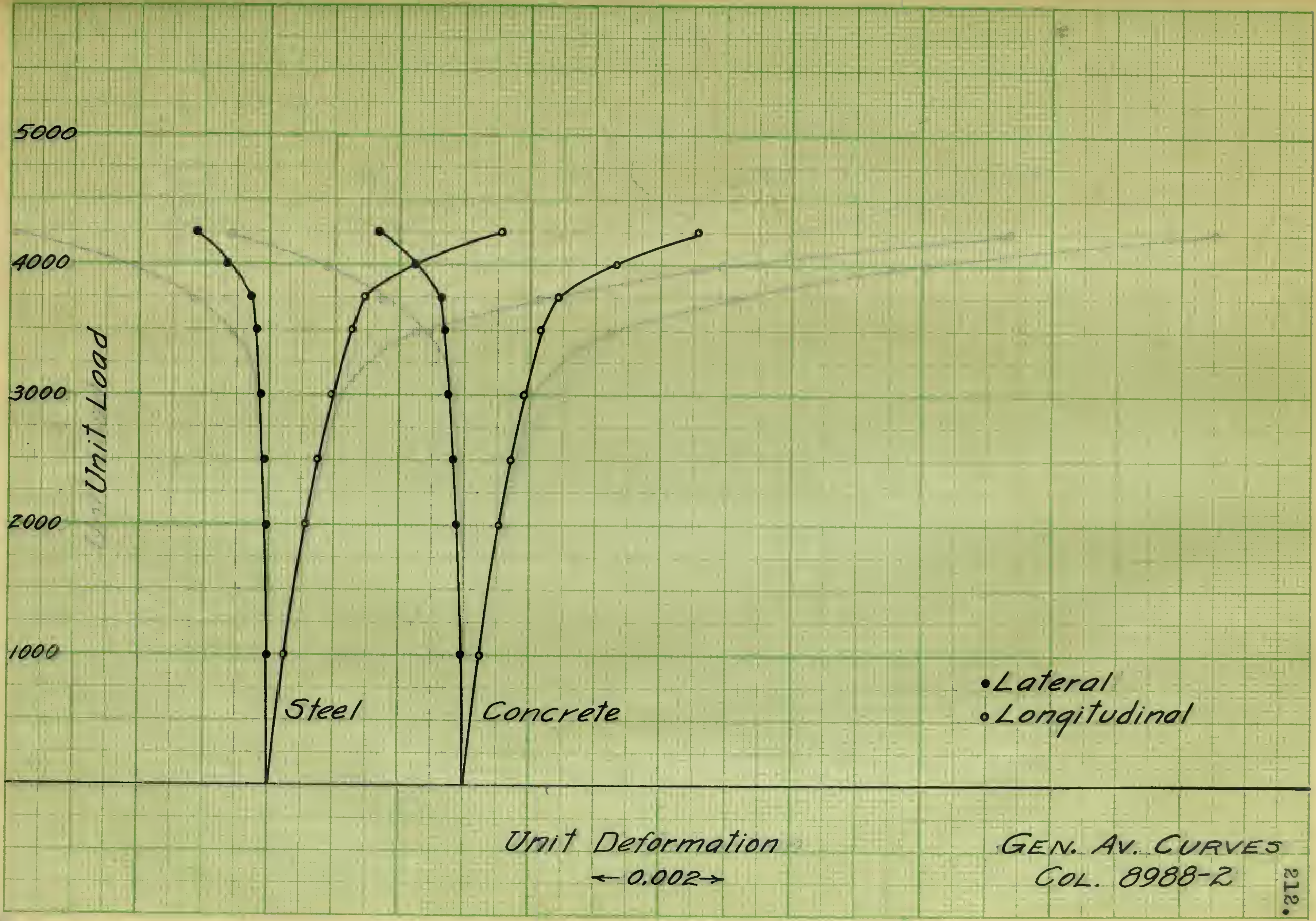

209
GEN. AV. CURVES
Col. 8986-2
•Lateral
∘Longitudinal
Unit Deformation
←.0002→
Concrete
Steel
Unit Load
1000
2000
3000
√

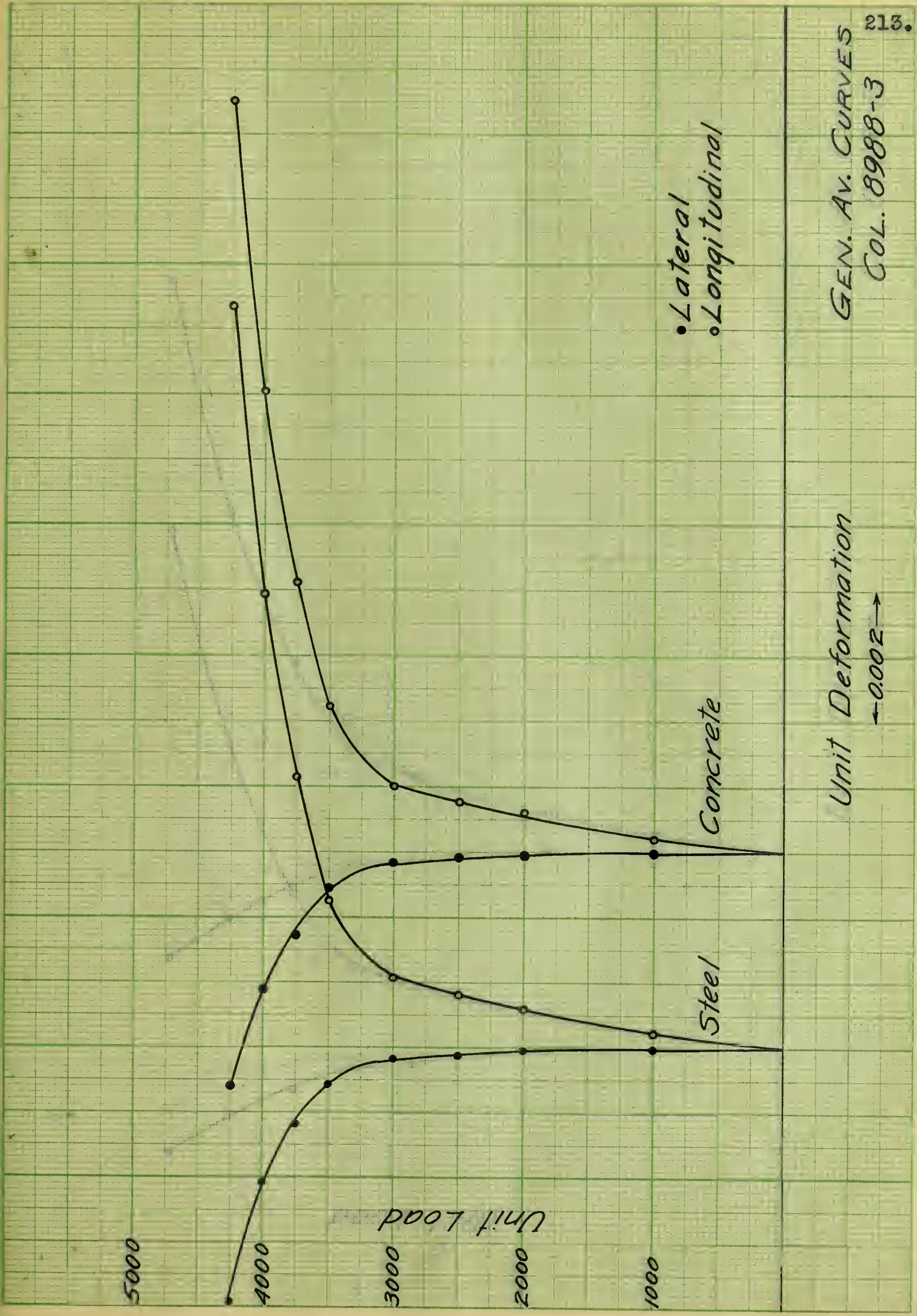


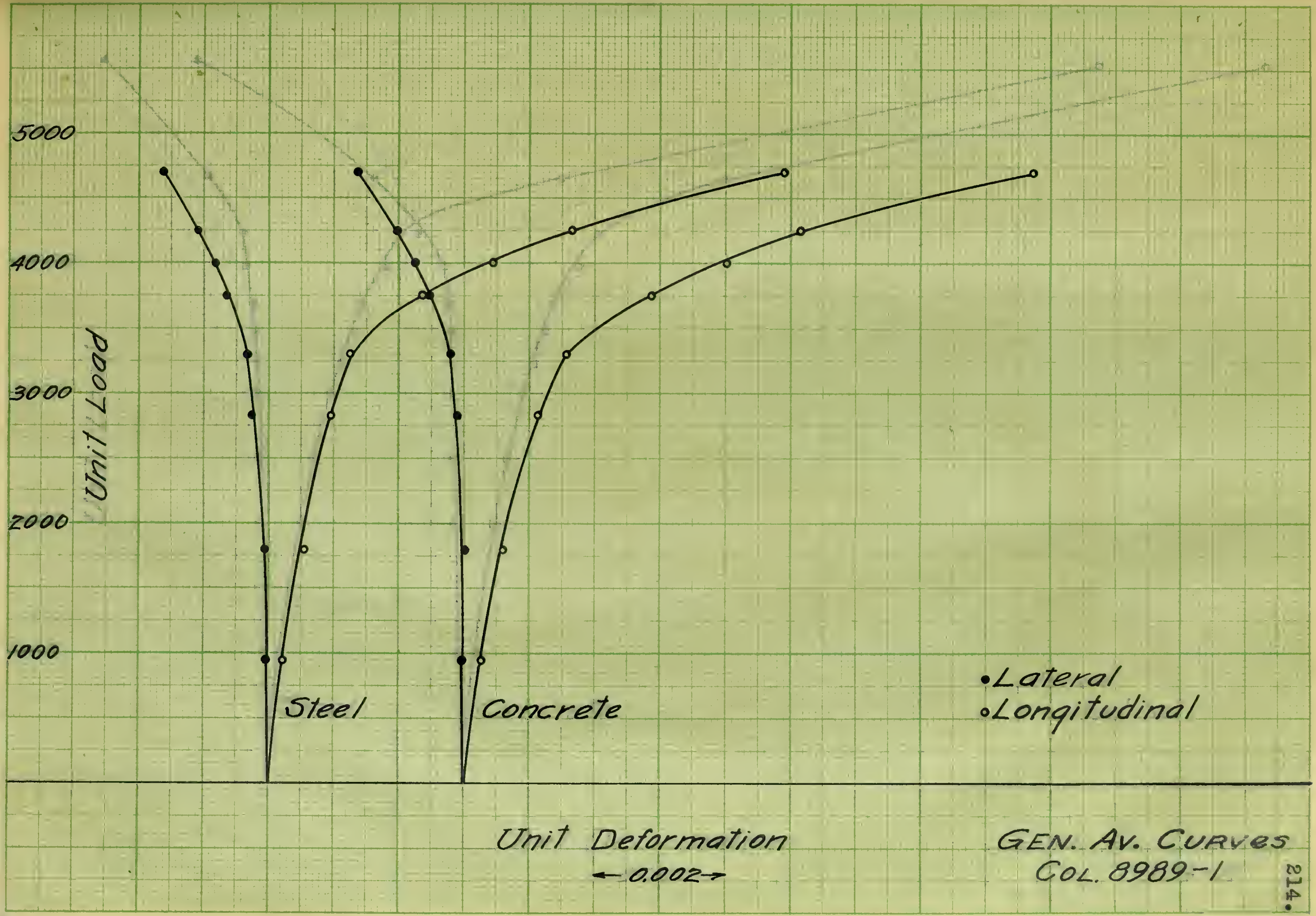
GEN. AV. CURVES
COL. 8986-3

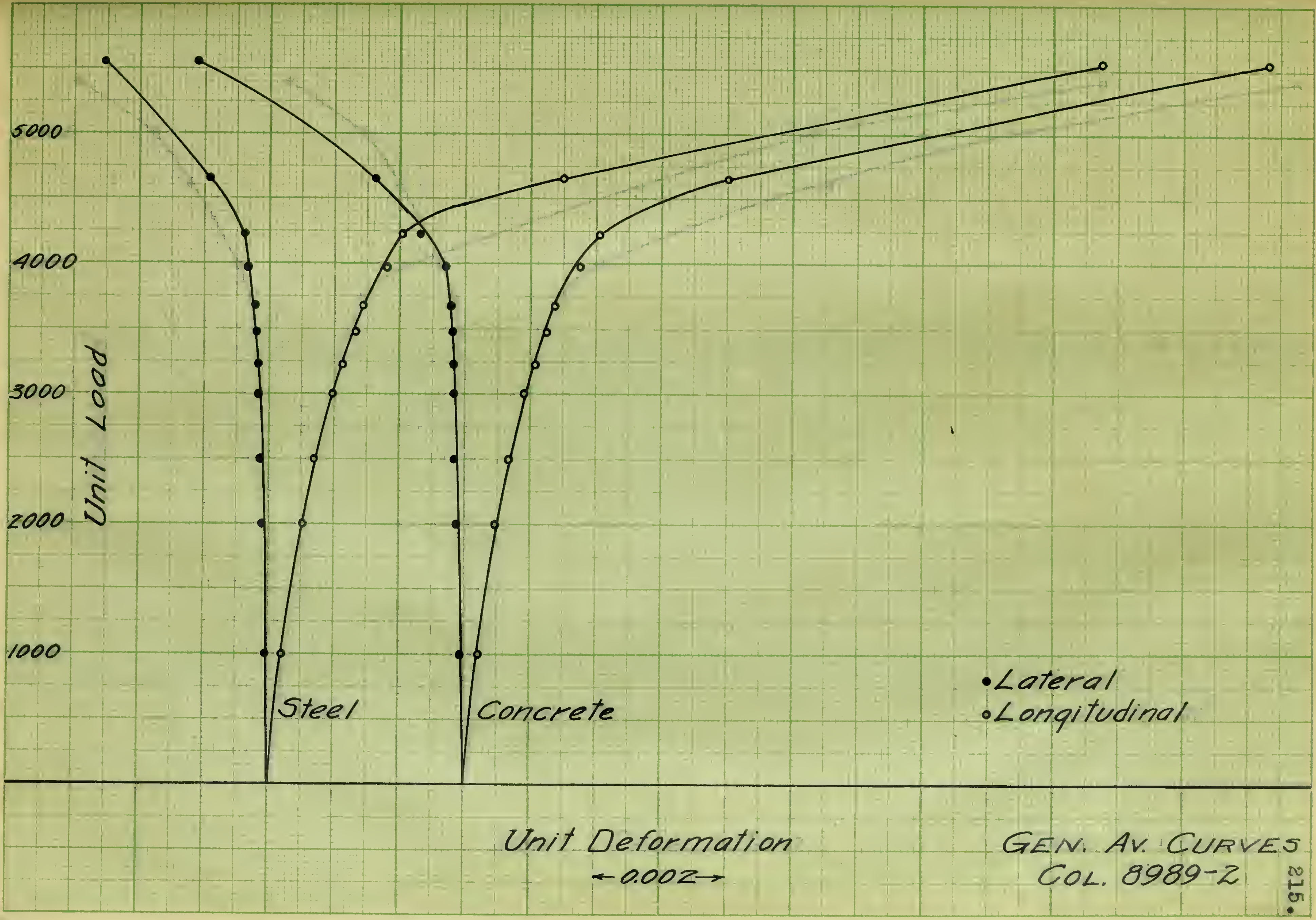


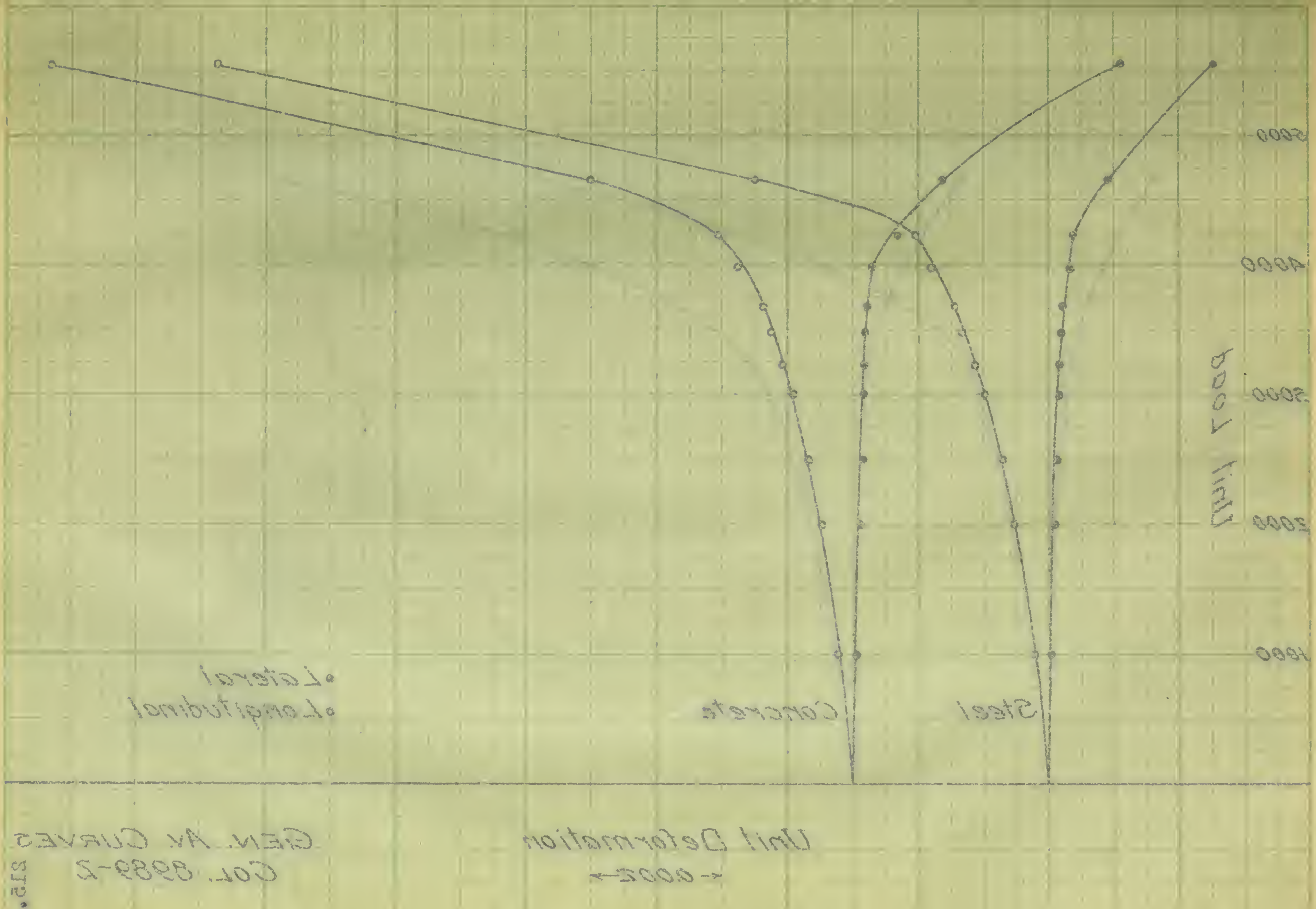
GEN. AV. CURVES
COL. 8988-1

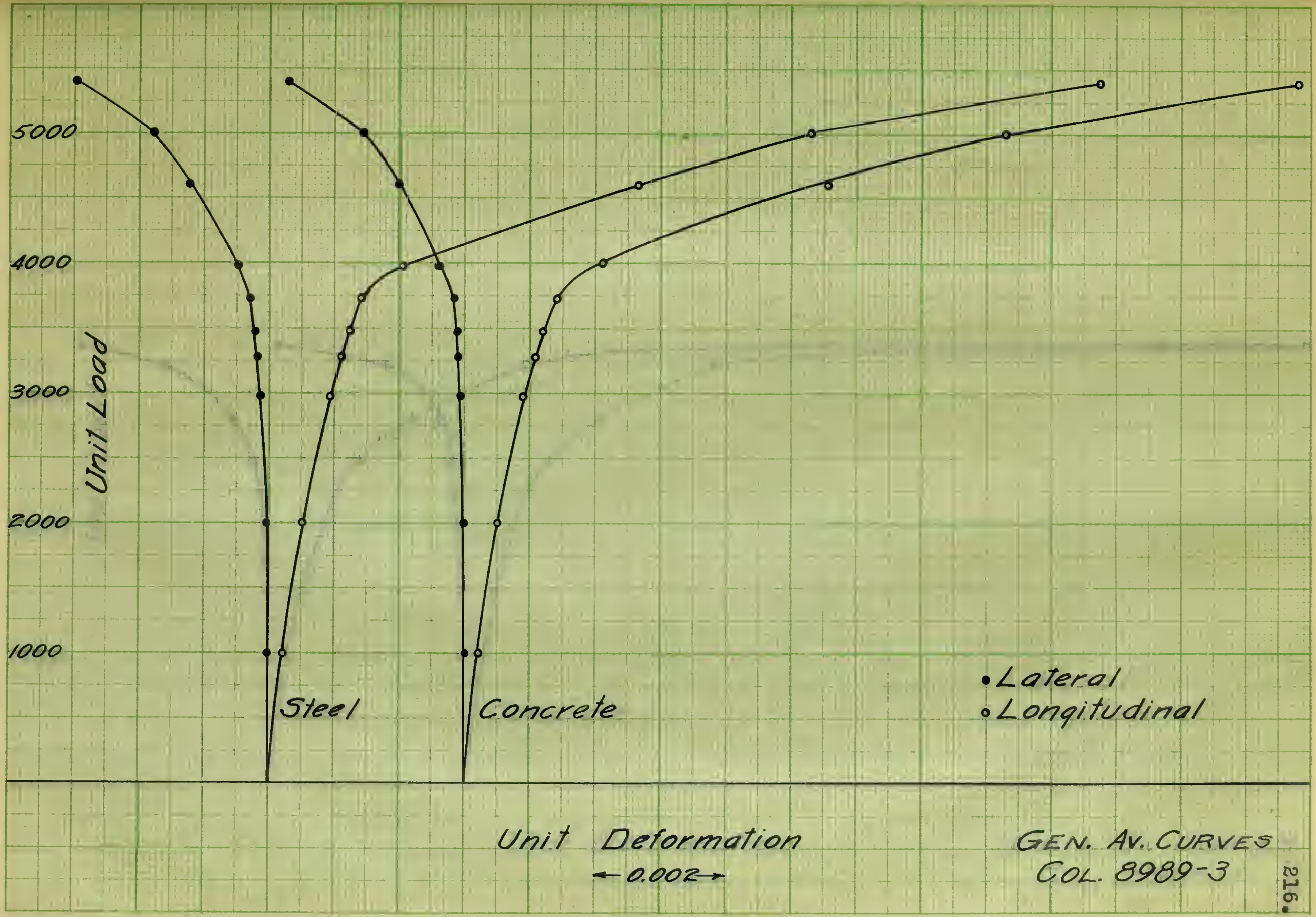

5000
4000
3000
2000
1000
Unit Load
Steel
Concrete
•Lateral
∘Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8988-2

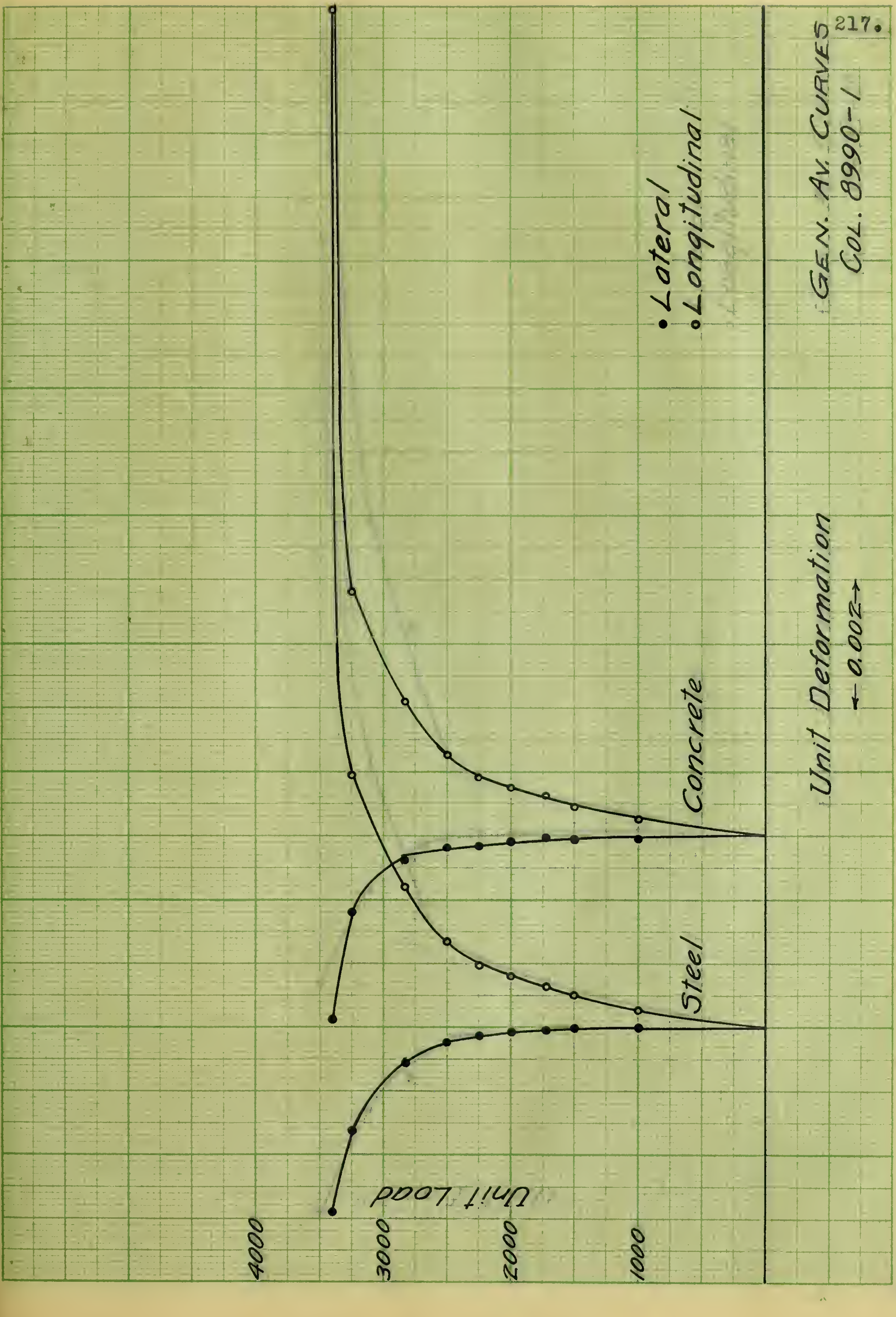

GEN. AV. CURVES
COL. 8988-3
● Lateral
○ Longitudinal
Concrete
Steel
Unit Deformation
←0.002→
Unit Load
5000
4000
3000
2000
1000


5000
4000
3000
2000
1000
Unit Load
Steel
Concrete
•Lateral
∘Longitudinal
Unit Deformation
← 0.002 →
GEN. AV. CURVES
COL. 8989-1

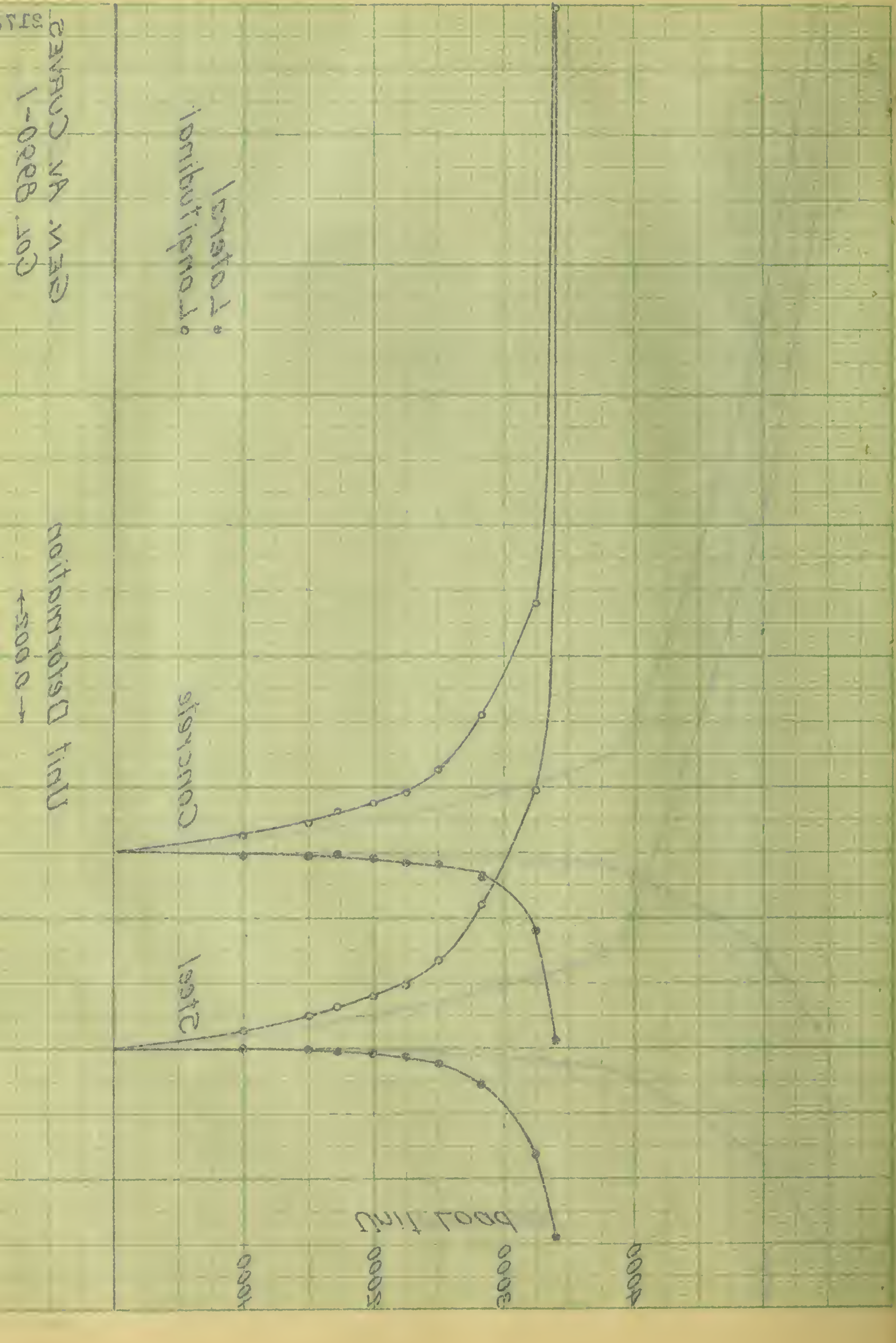

5000
4000
3000
2000
1000
Unit Load
Steel
Concrete
•Lateral
∘Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8989-2

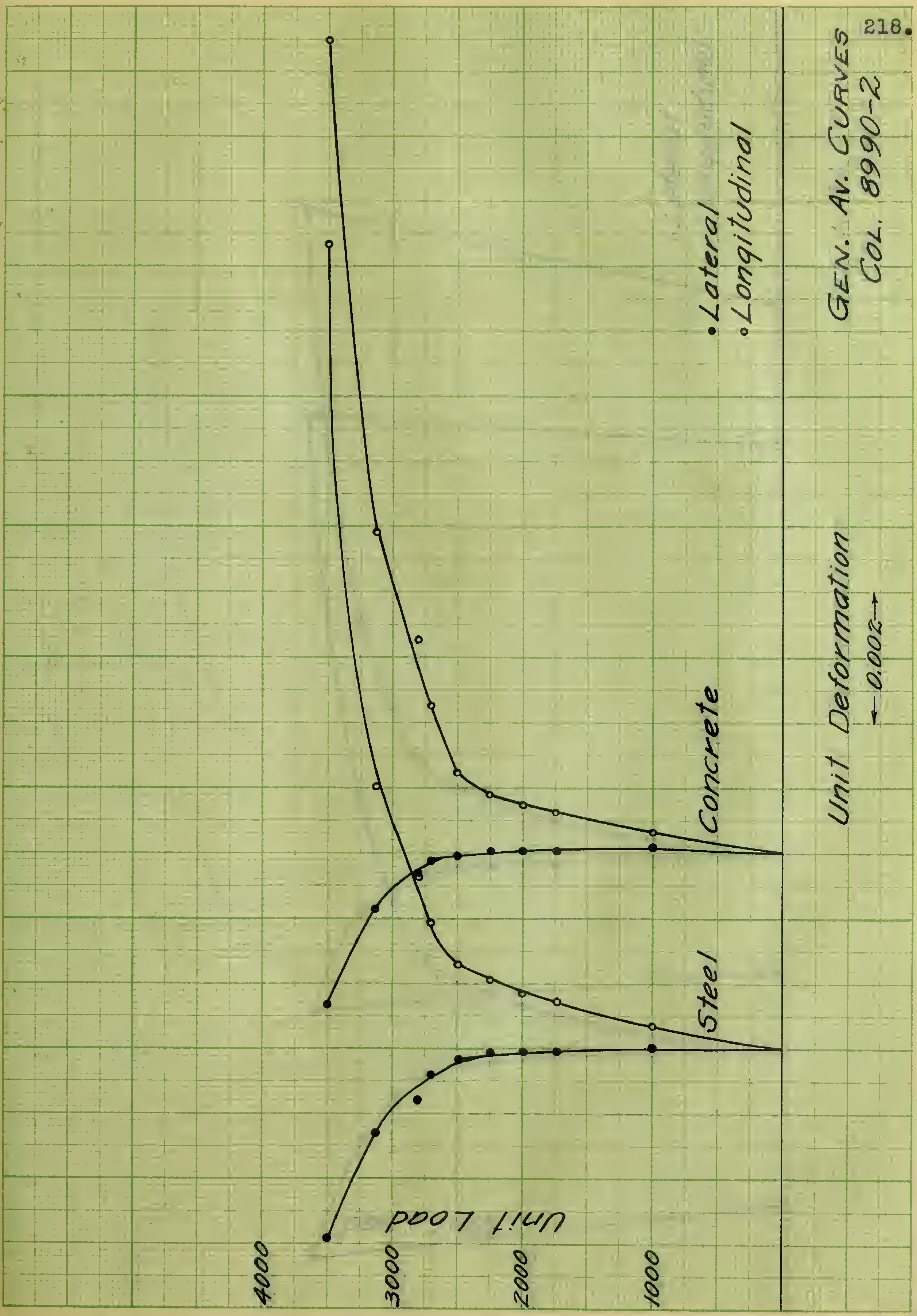

Gen. Av. Curves
Col. 8989-2
Unit Deformation
←.0002→
Unit Load
1000
2000
3000
4000
5000
•Lateral
•Longitudinal
Concrete
Steel
215.

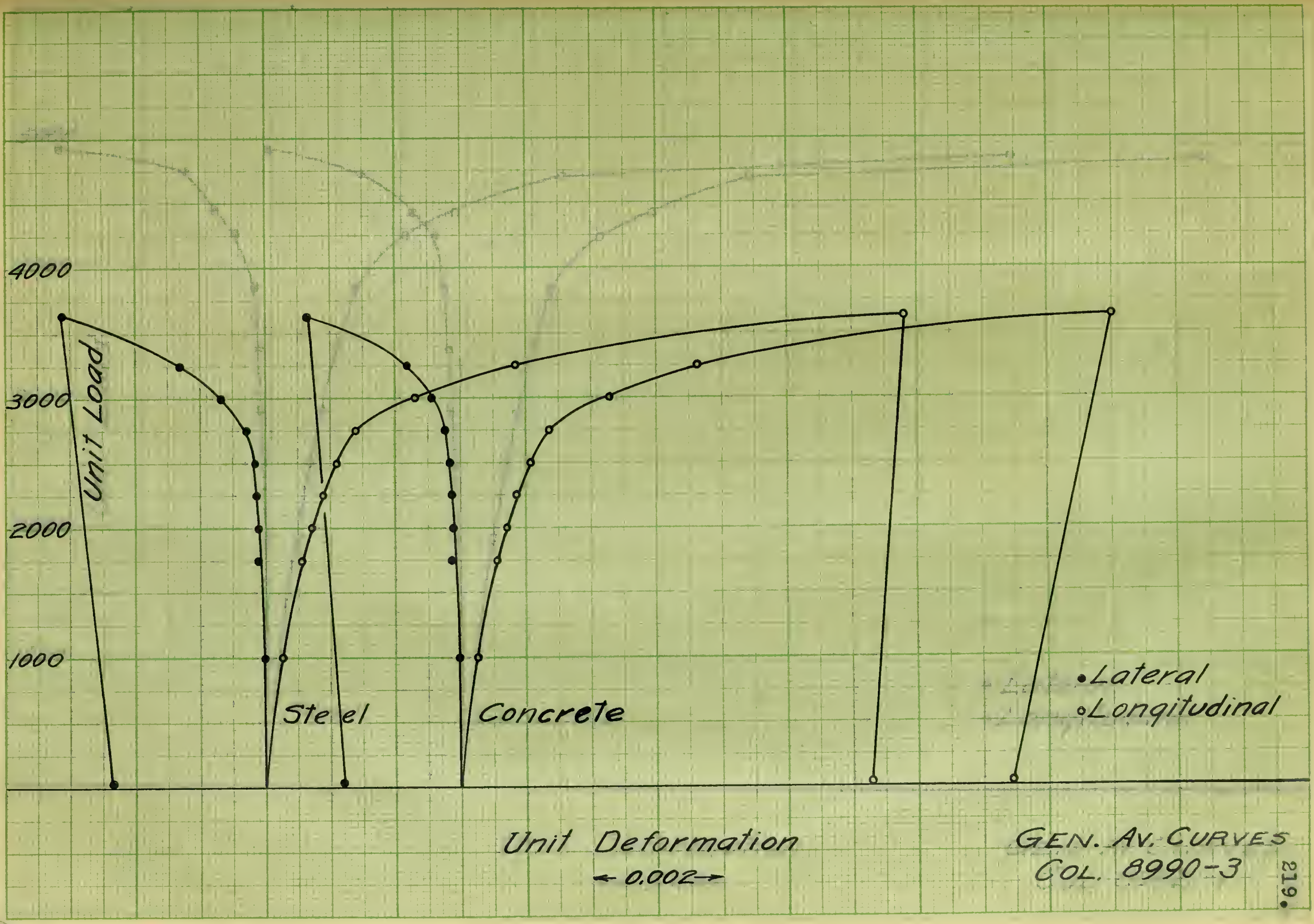

5000
4000
3000
2000
1000
Unit Load
Steel
Concrete
● Lateral
○ Longitudinal
Unit Deformation
← 0.002 →
GEN. AV. CURVES
COL. 8989-3

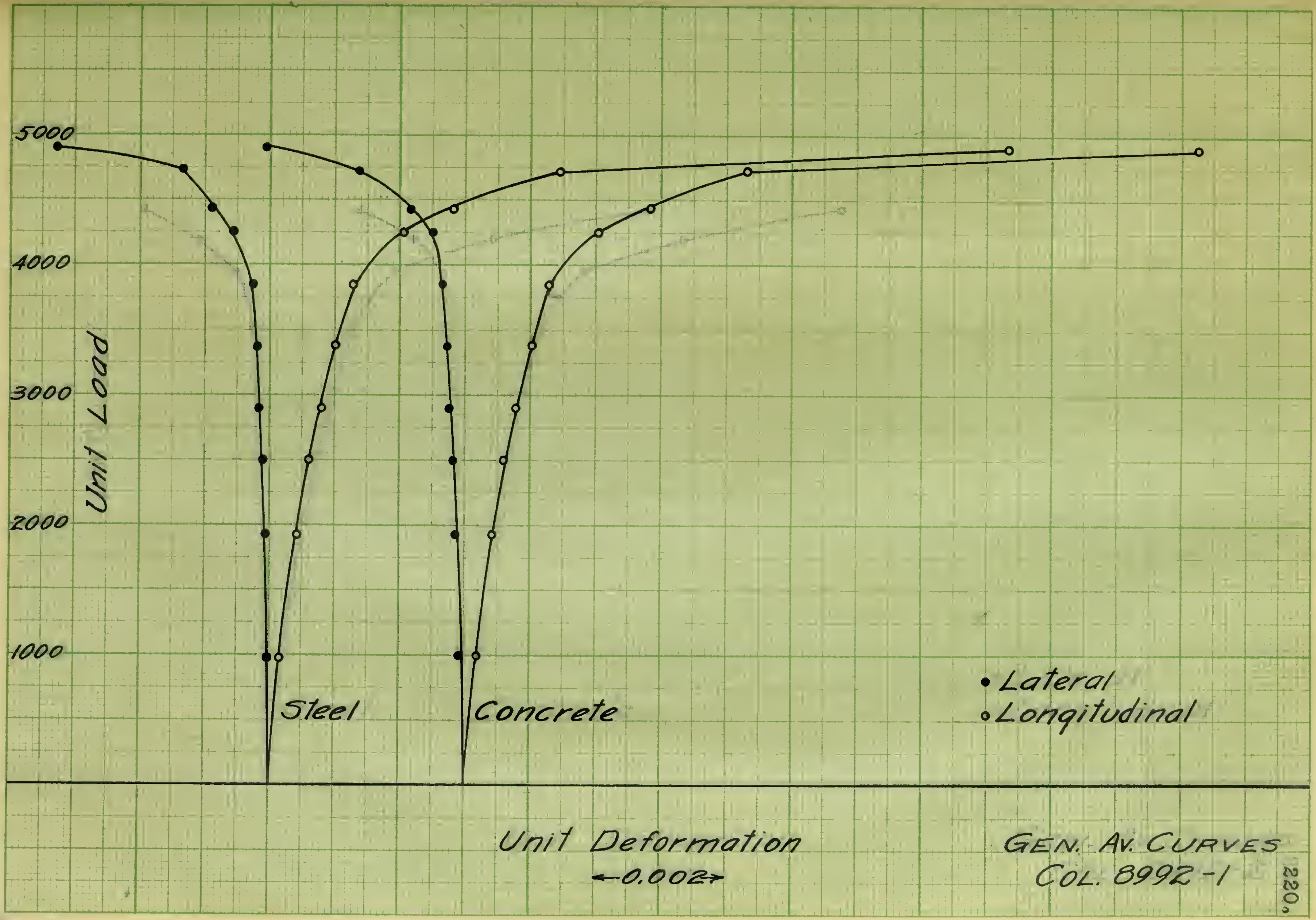


GEN. AV. CURVES
COL. 8990-1

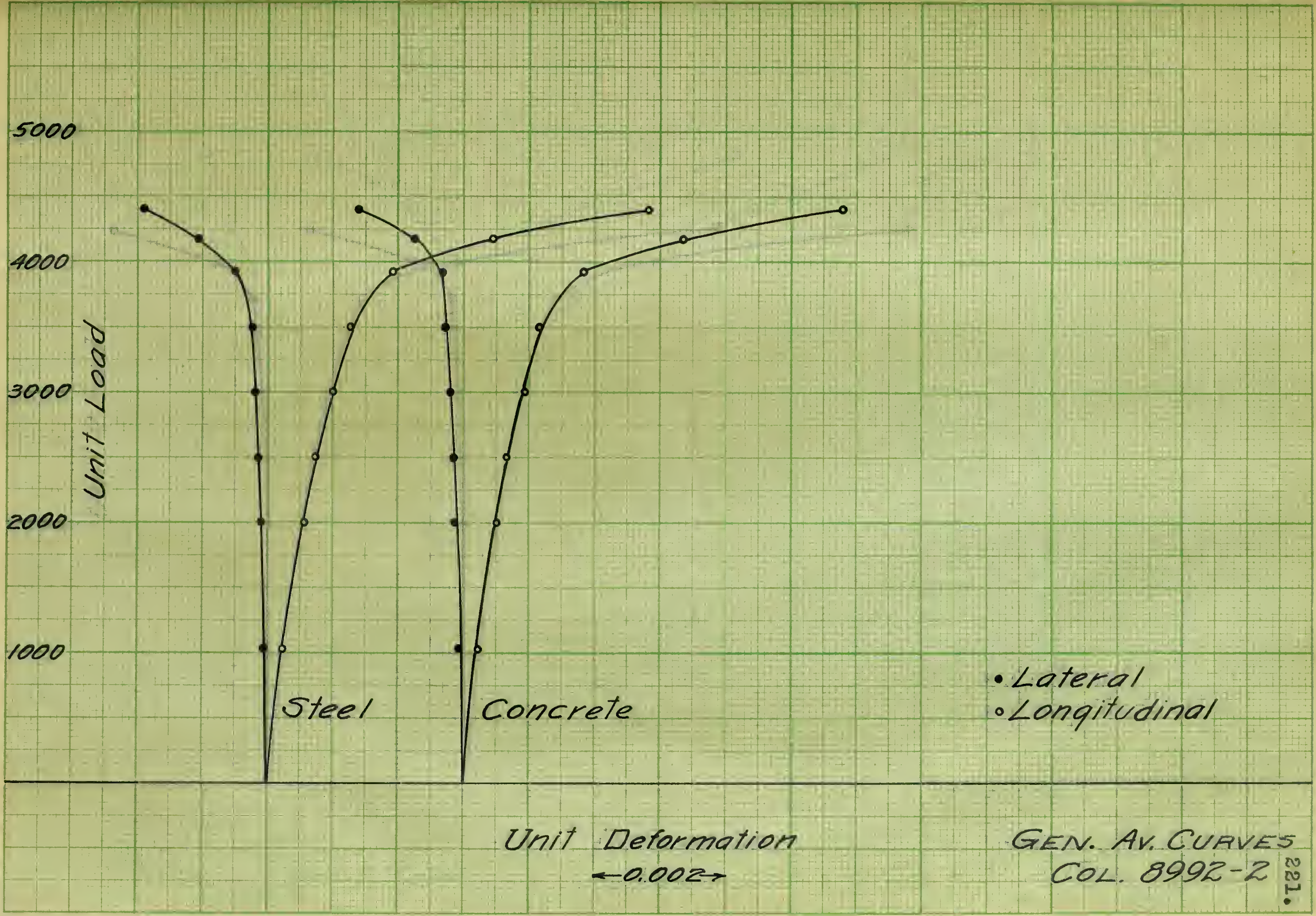

GEN. AV. CURVES
Col. 8990-1
Unit Deformation
←0.0002→
• Lateral
○ Longitudinal
Concrete
Steel
Unit Load
1000
2000
3000
4000

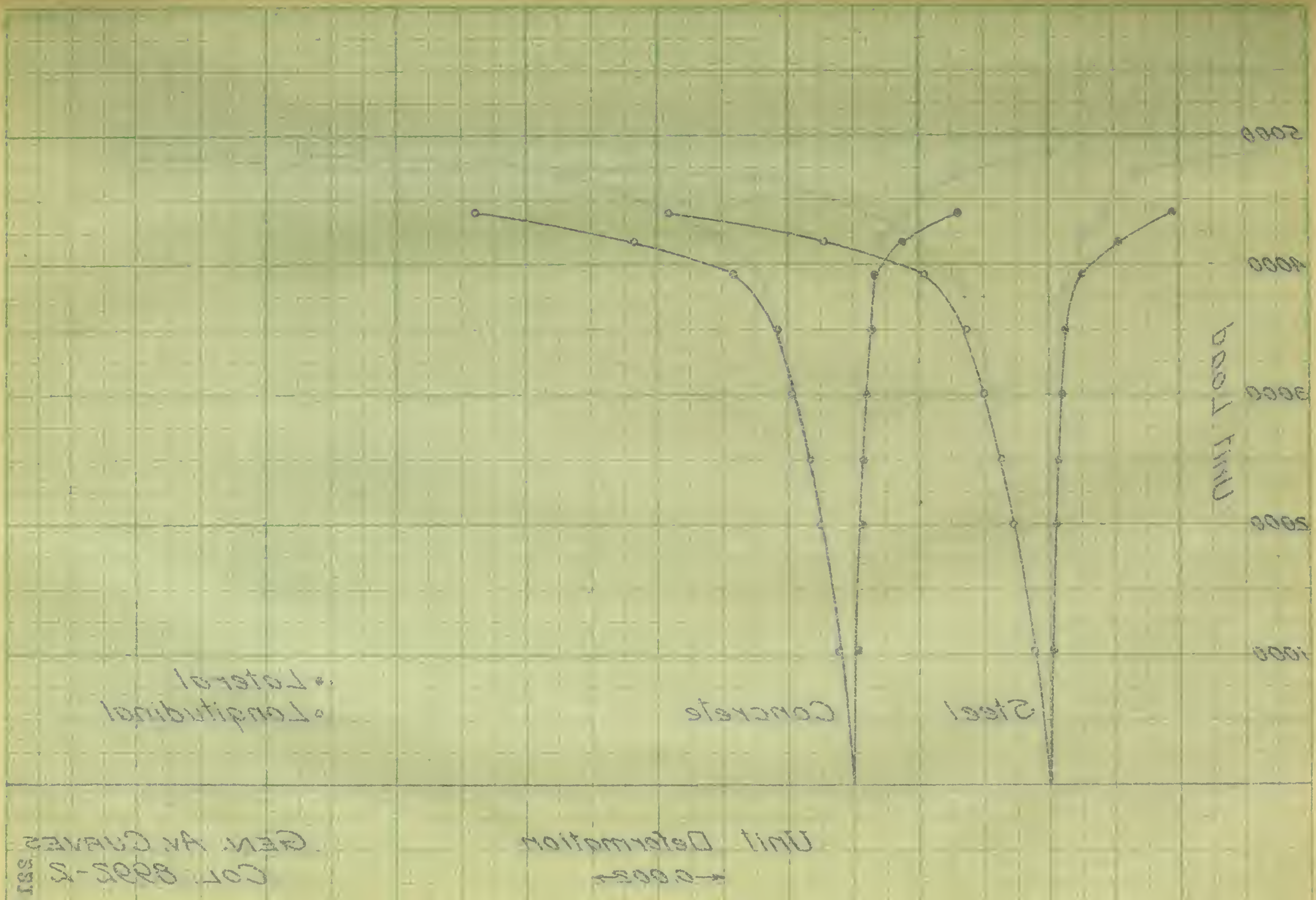

GEN. AV. CURVES
COL. 8990-2
• Lateral
∘ Longitudinal
Concrete
Steel
Unit Deformation
← 0.002 →
Unit Load
4000
3000
2000
1000

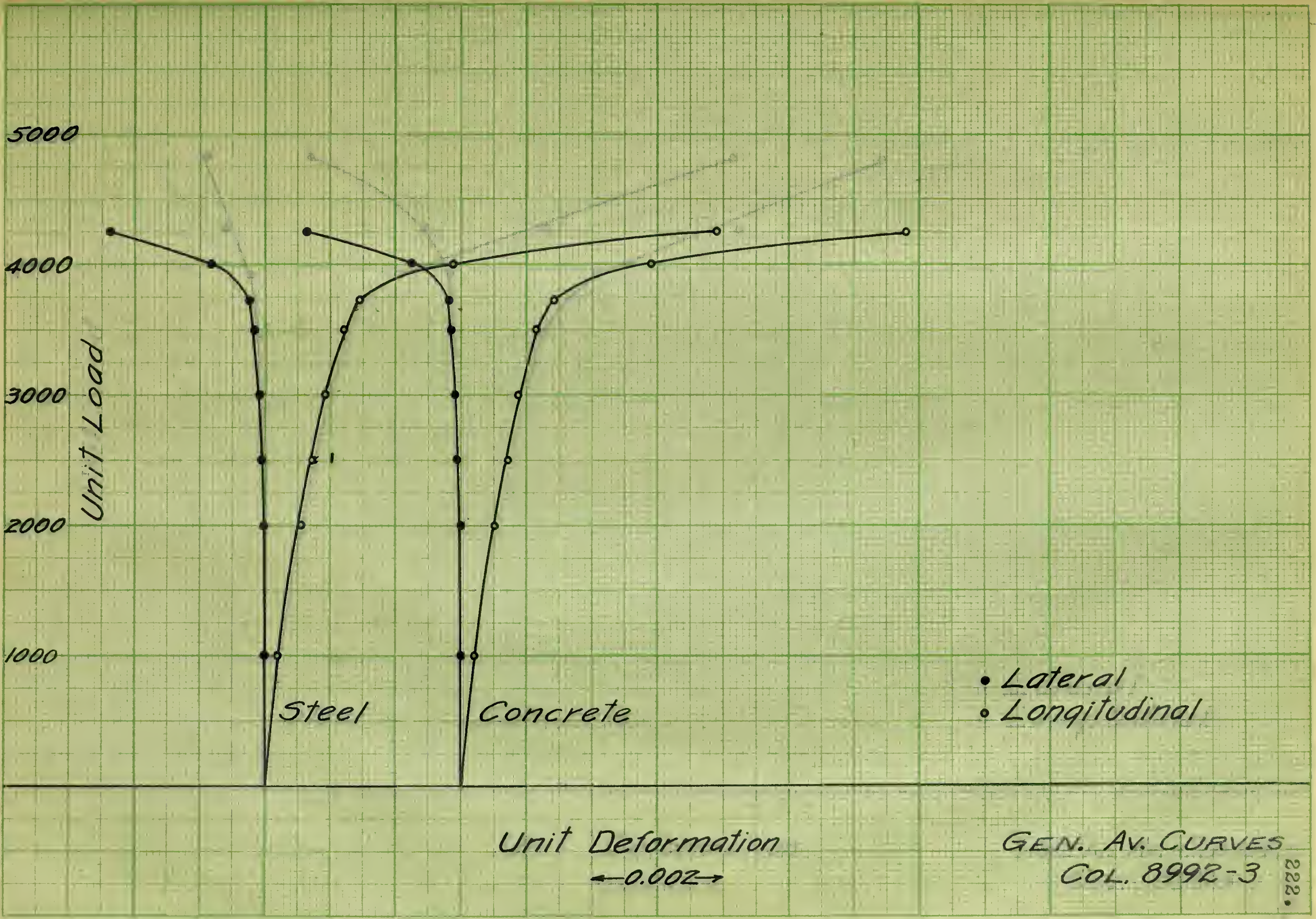

4000
3000
2000
1000
Unit Load
Steel
Concrete
•Lateral
◦Longitudinal
Unit Deformation
← 0.002 →
GEN. AV. CURVES
COL. 8990-3

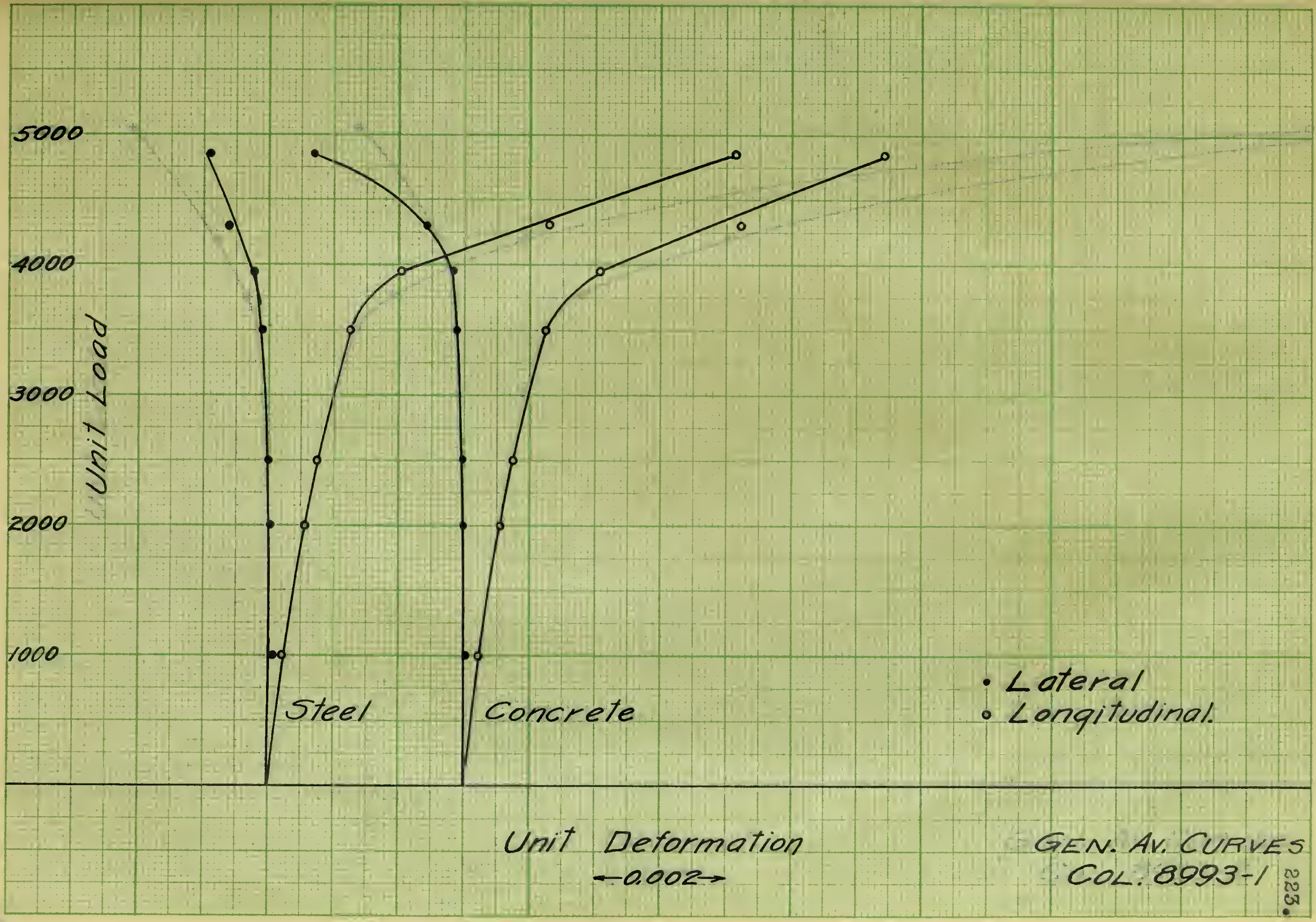


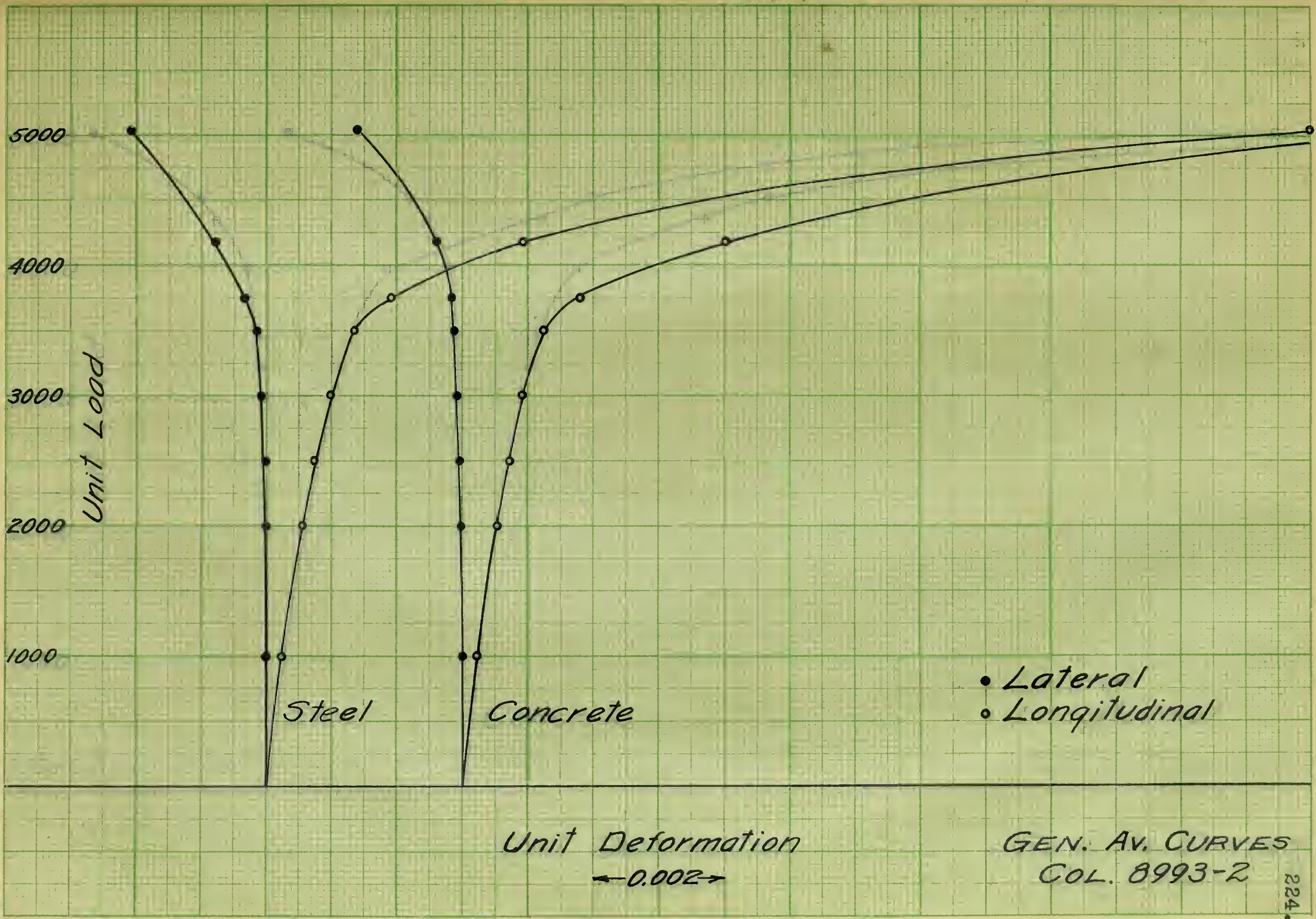
GEN. AV. CURVES
COL. 8992-1


5000
4000
3000
2000
1000
Unit Load
Steel
Concrete
• Lateral
∘ Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8992-2


Unit Load
5000
4000
3000
2000
1000
Concrete
Steel
• Lateral
∘ Longitudinal
Unit Deformation
←.0002→
Gen. Av. Curves
Col. 8992-2
221


5000
4000
3000
2000
1000
Unit Load
Steel
Concrete
• Lateral
∘ Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8992-3


5000
4000
3000
2000
1000
Unit Load
Steel
Concrete
• Lateral
∘ Longitudinal.
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8993-1



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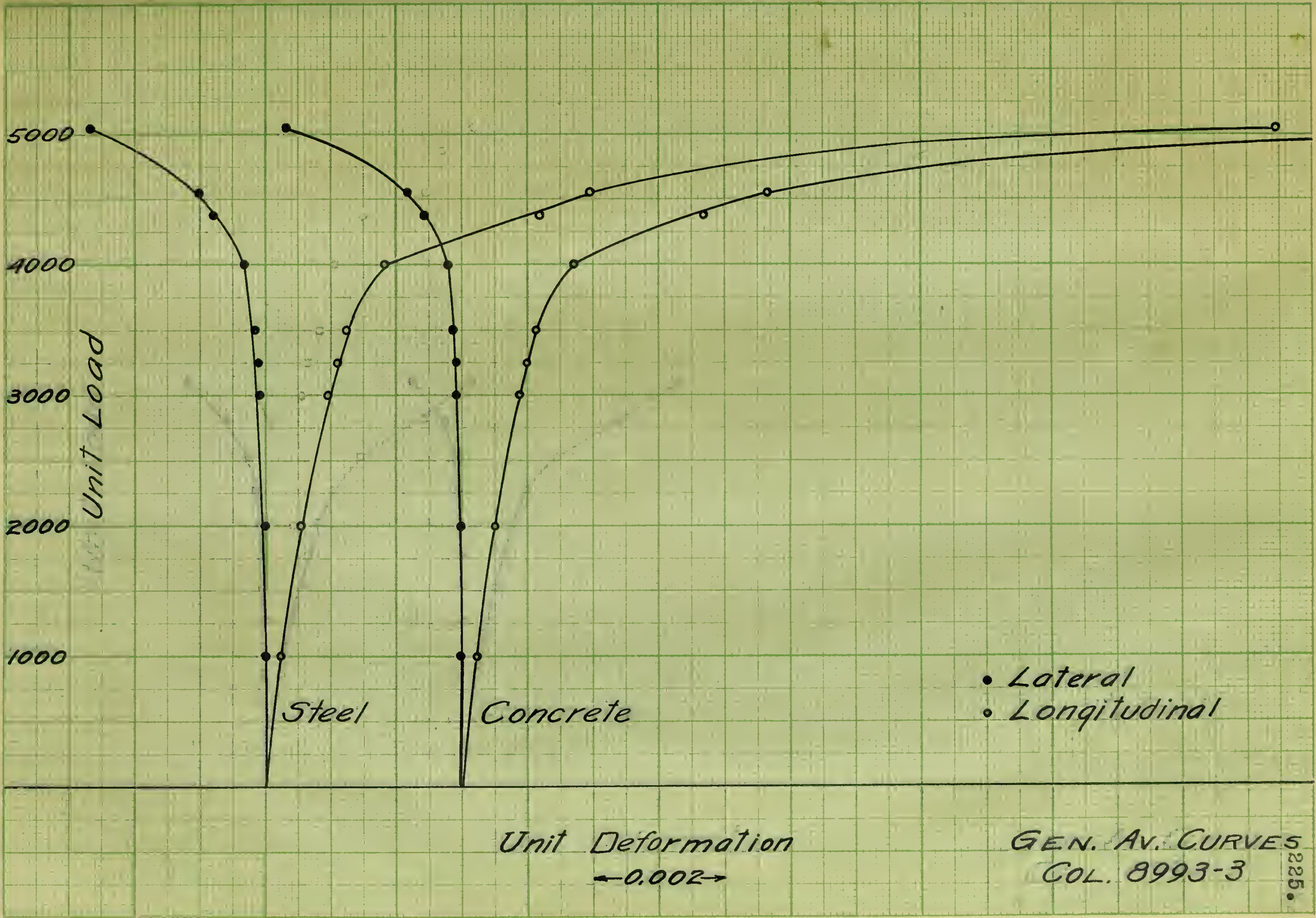
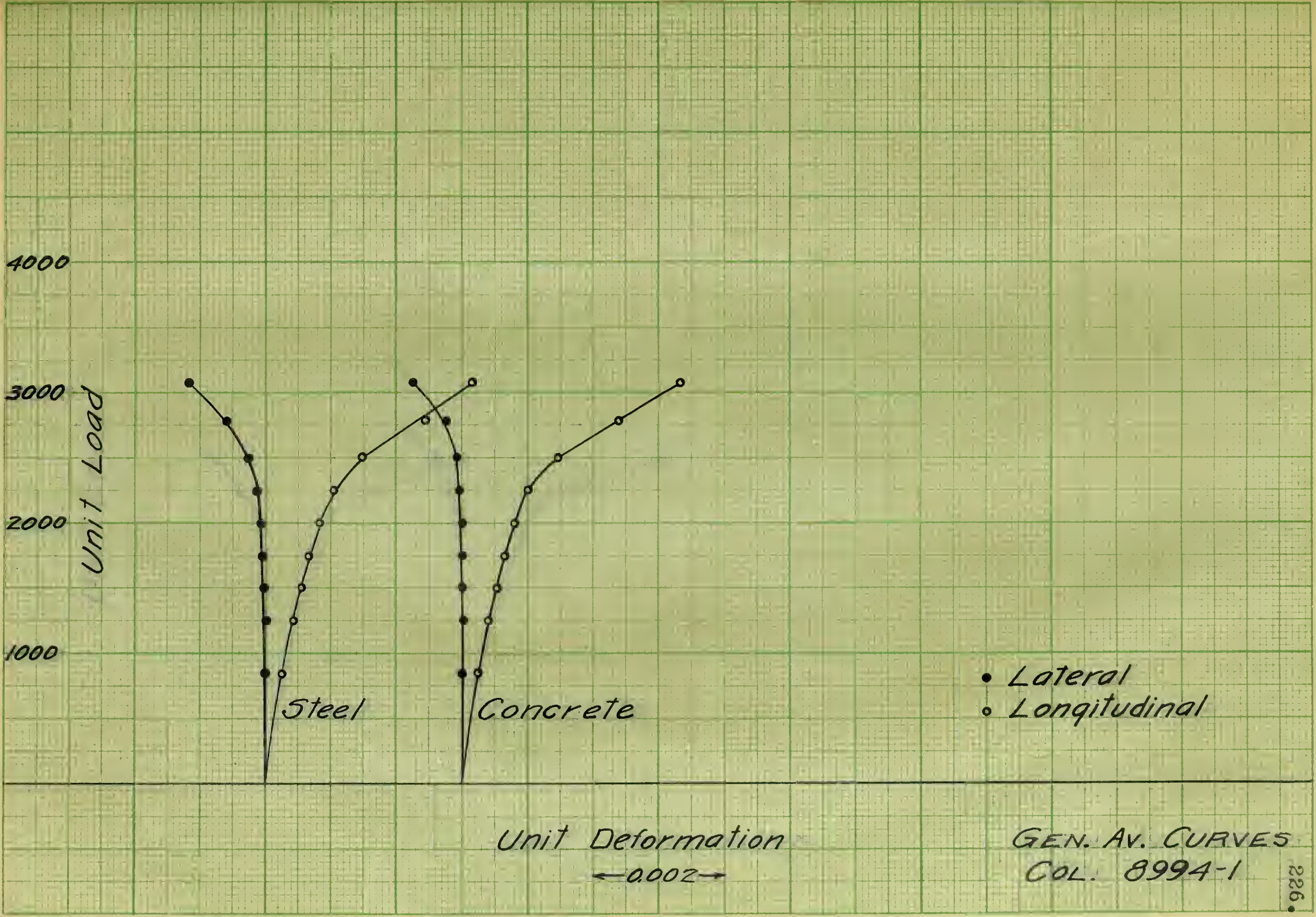
COL. 8993-2



GEN. AV. CURVES
COL. 8993-3



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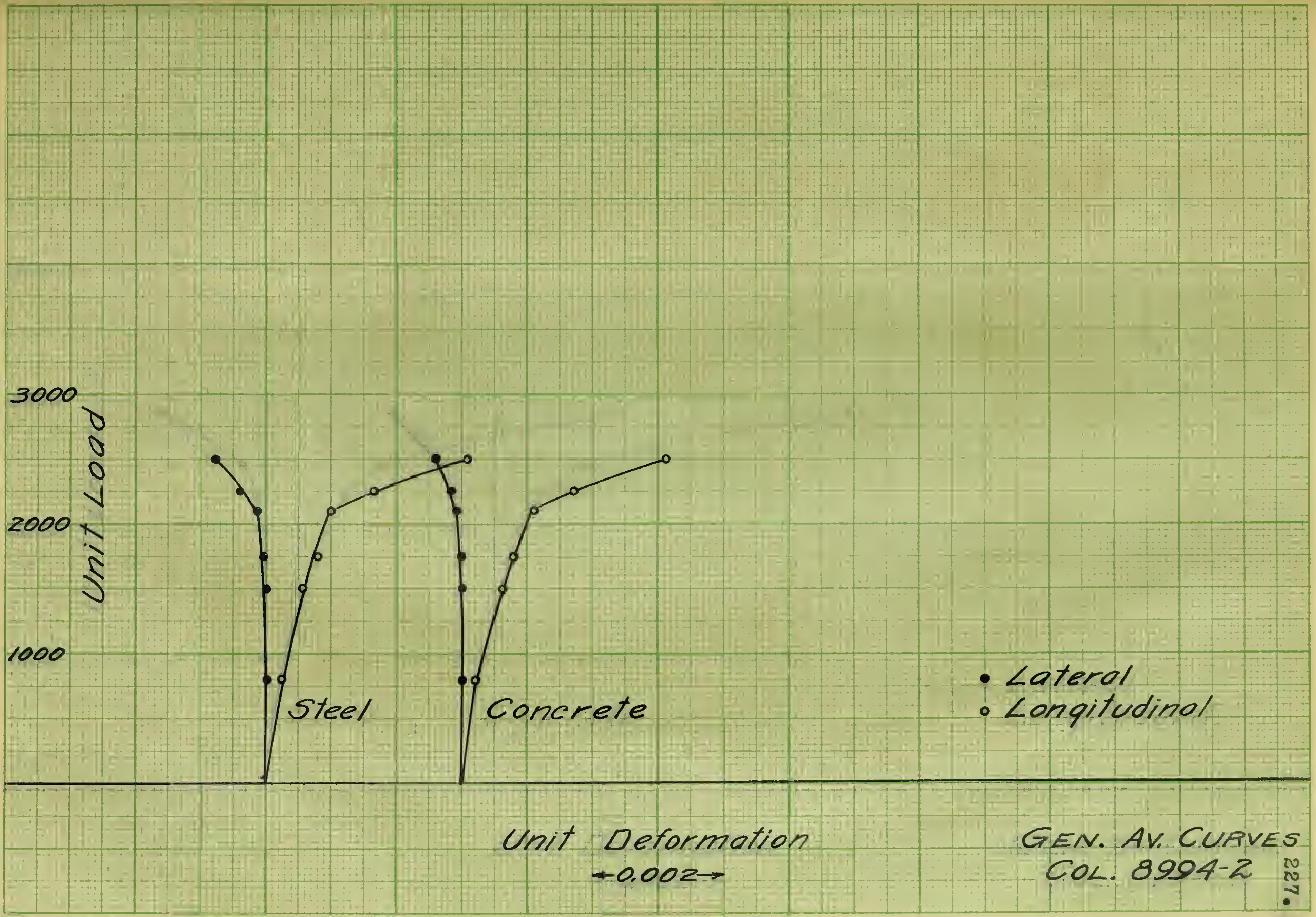
COL. 8994-1



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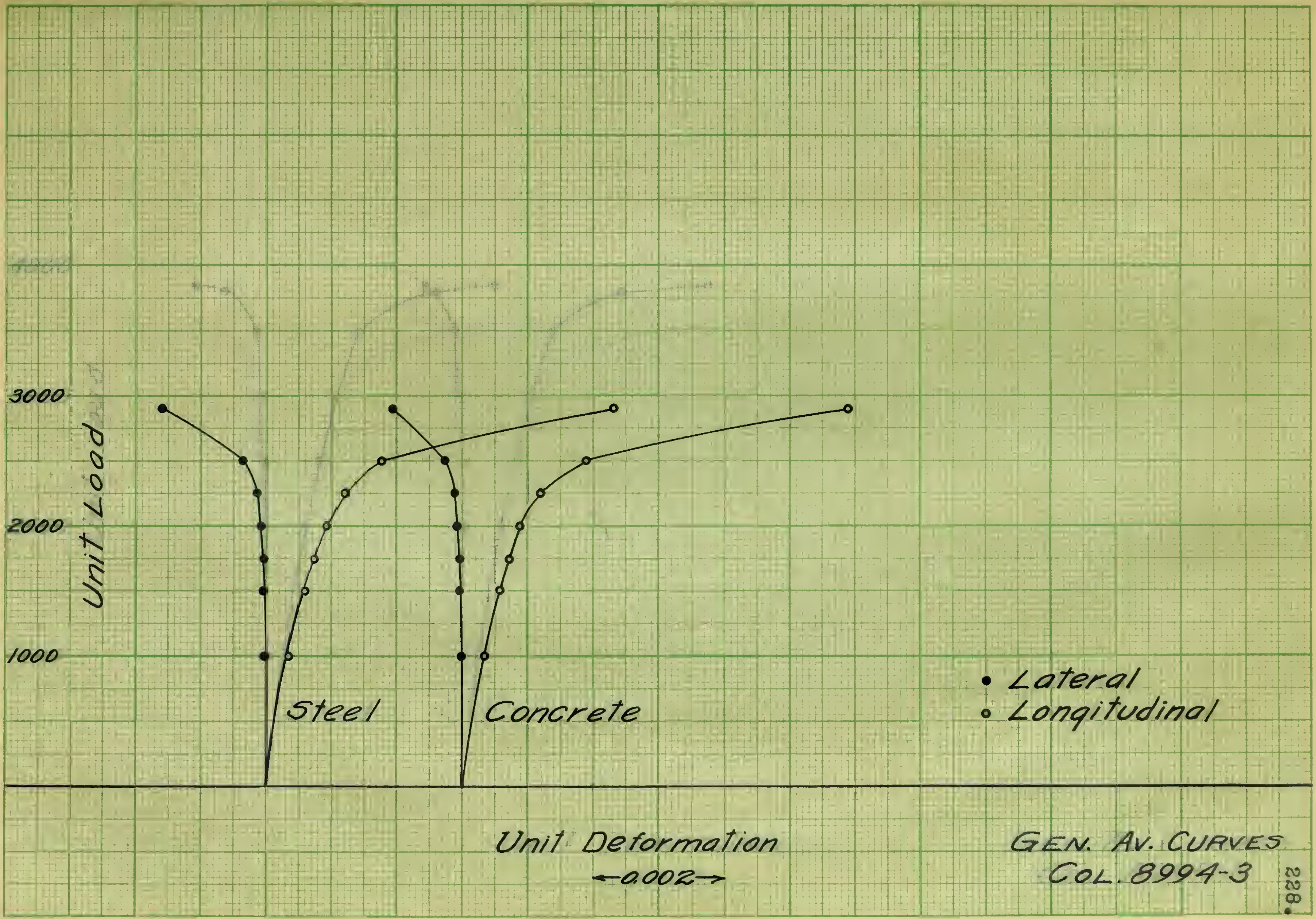
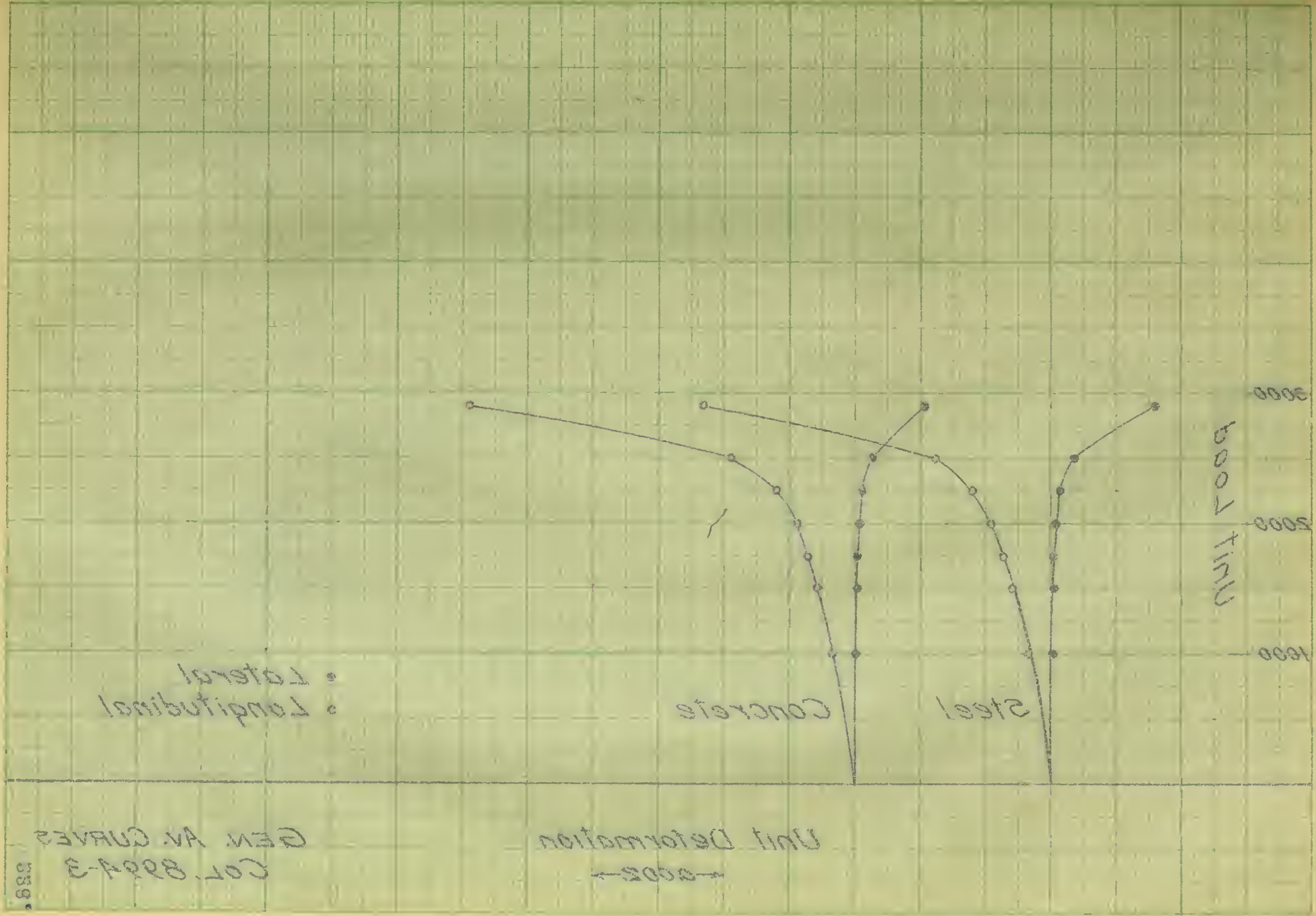
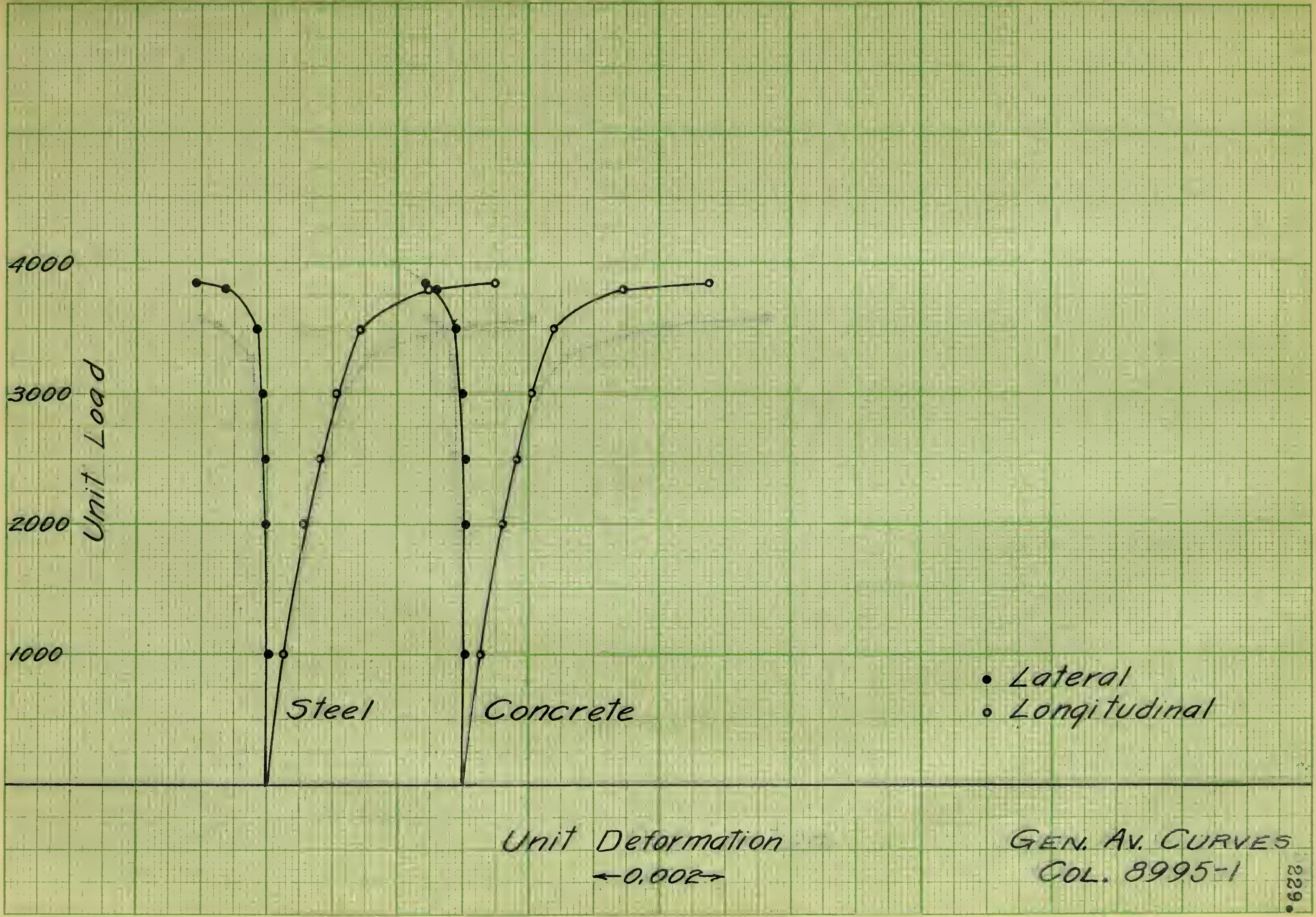
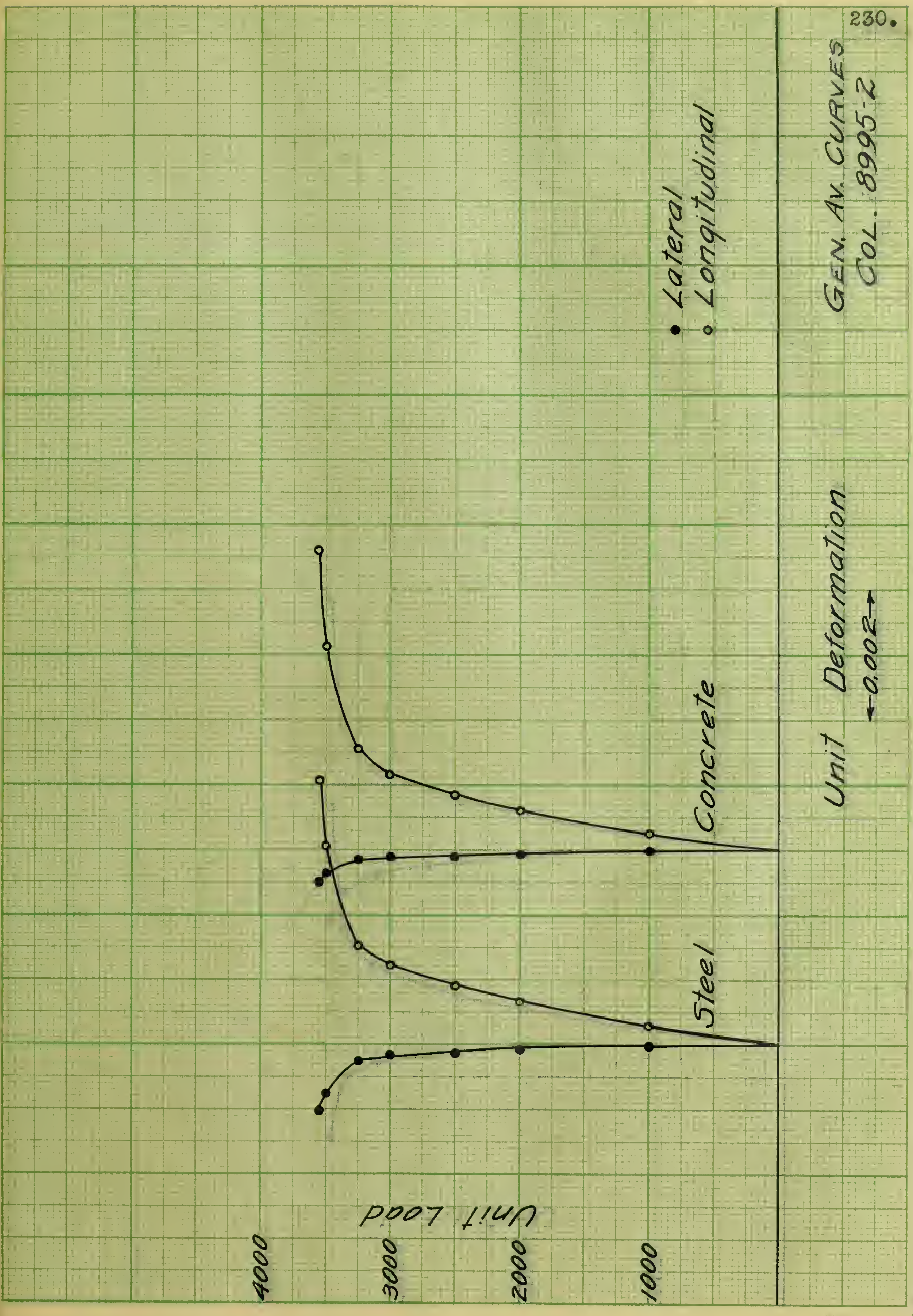
COL. 8994-2

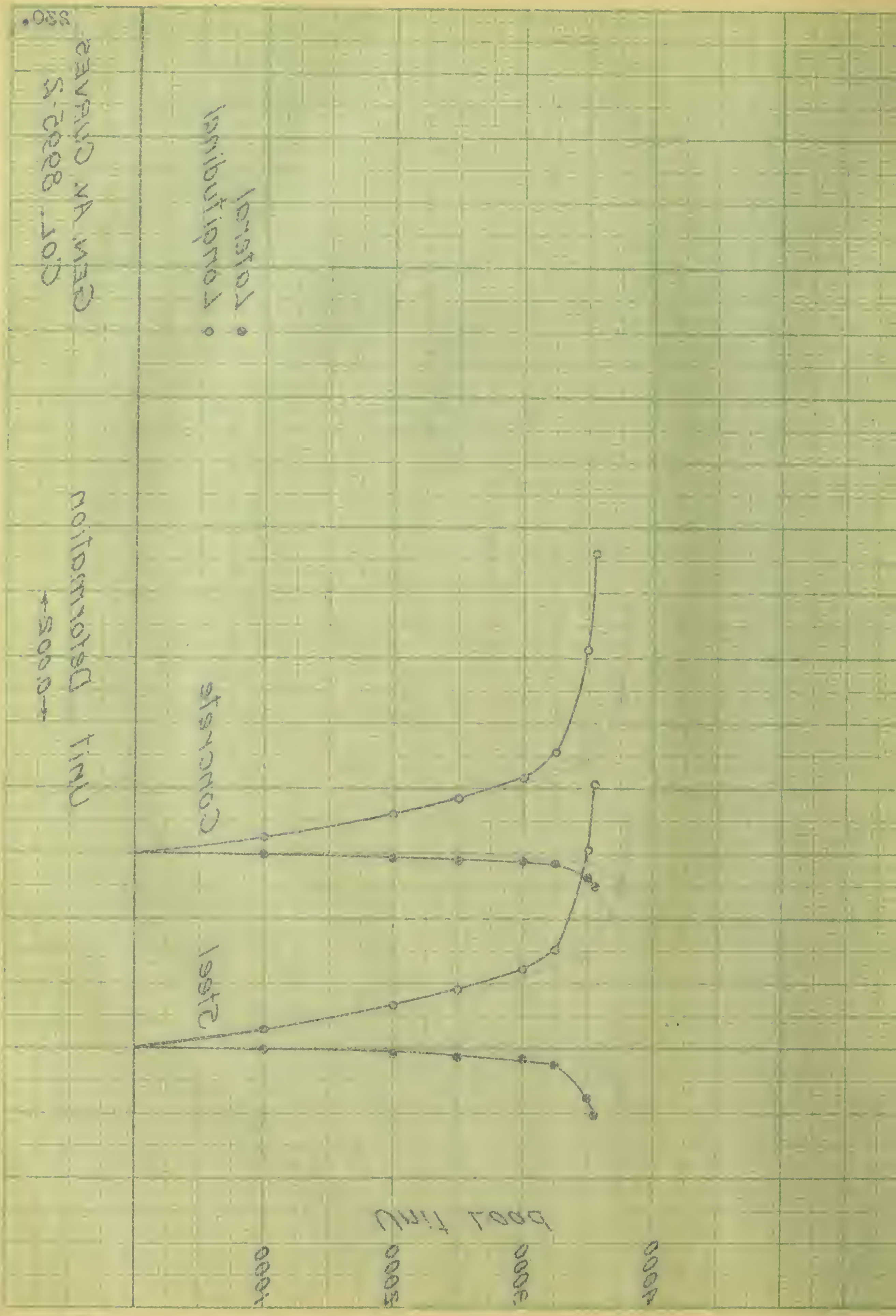

3000
2000
1000
Unit Load
Steel
Concrete
• Lateral
○ Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8994-3

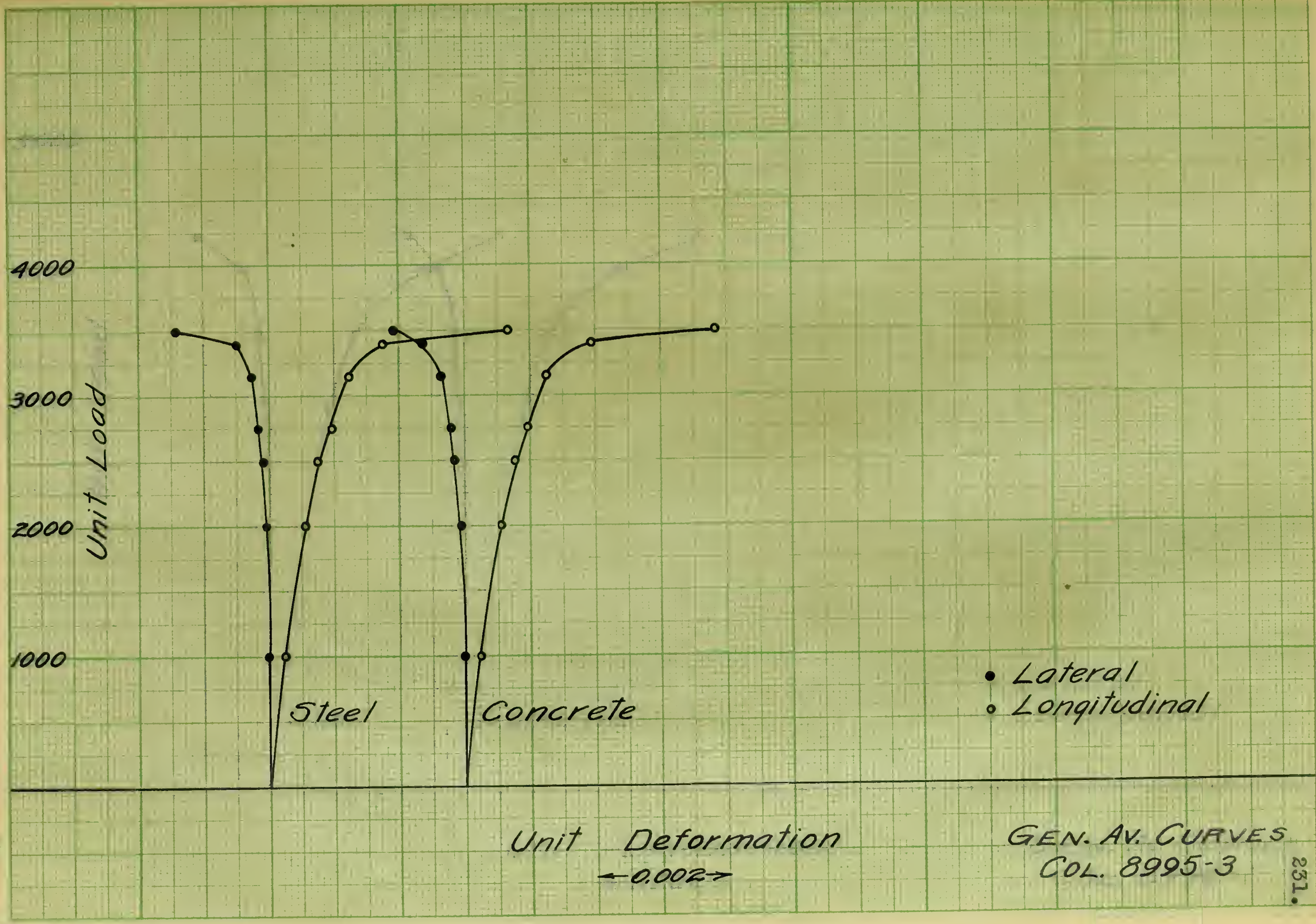




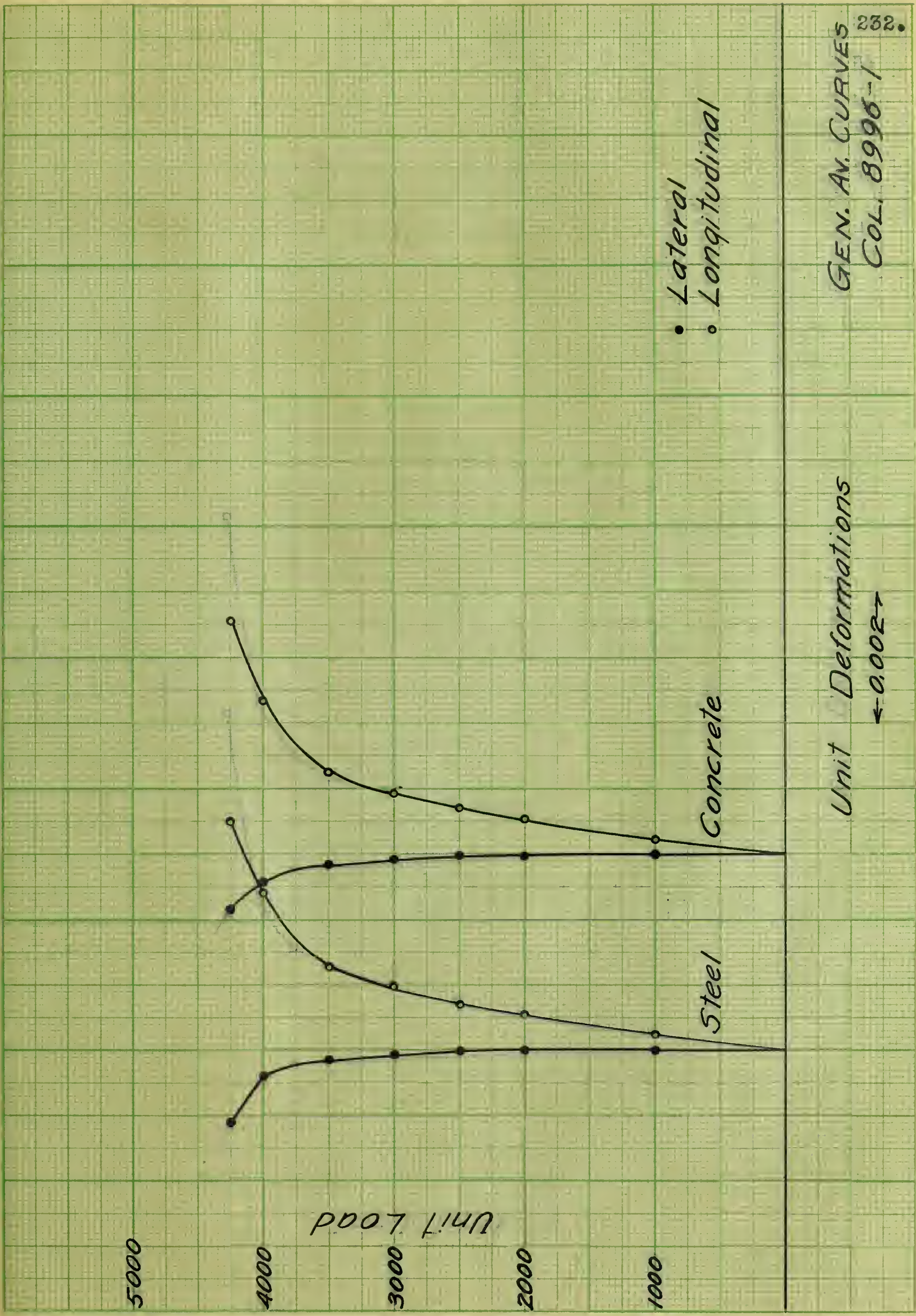
GEN. AV. CURVES
COL. 8995-1


● Lateral
○ Longitudinal
Concrete
Steel
Unit Deformation
←0.002→
Unit Load
4000
3000
2000
1000
GEN. AV. CURVES
COL. 8995-2

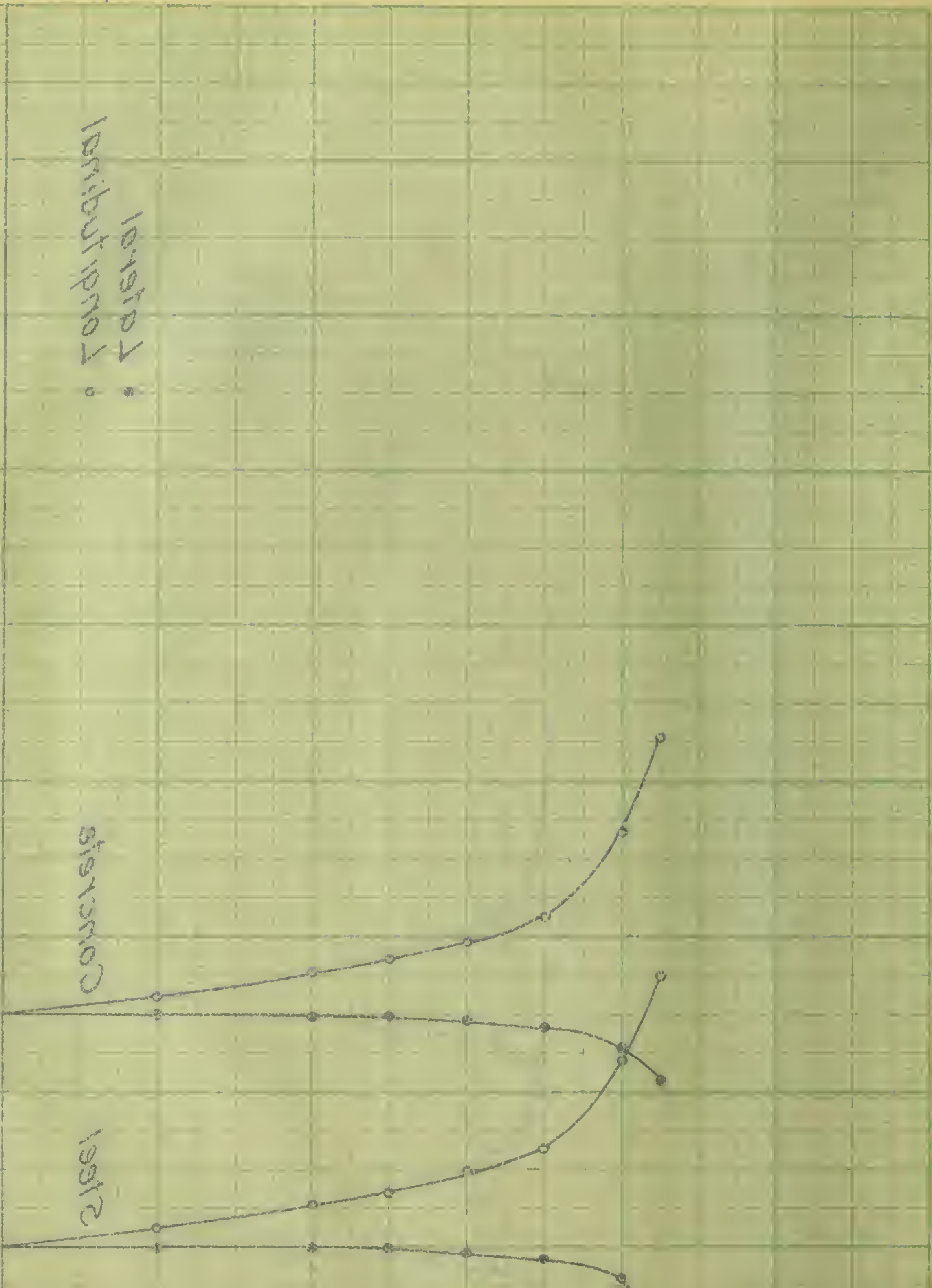

Gen. Av. Curves
Col. 3995-2
230.
Unit Deformation
←.0002→
• Lateral
○ Longitudinal
Concrete
Steel
Unit Load
1000
2000
3000
4000

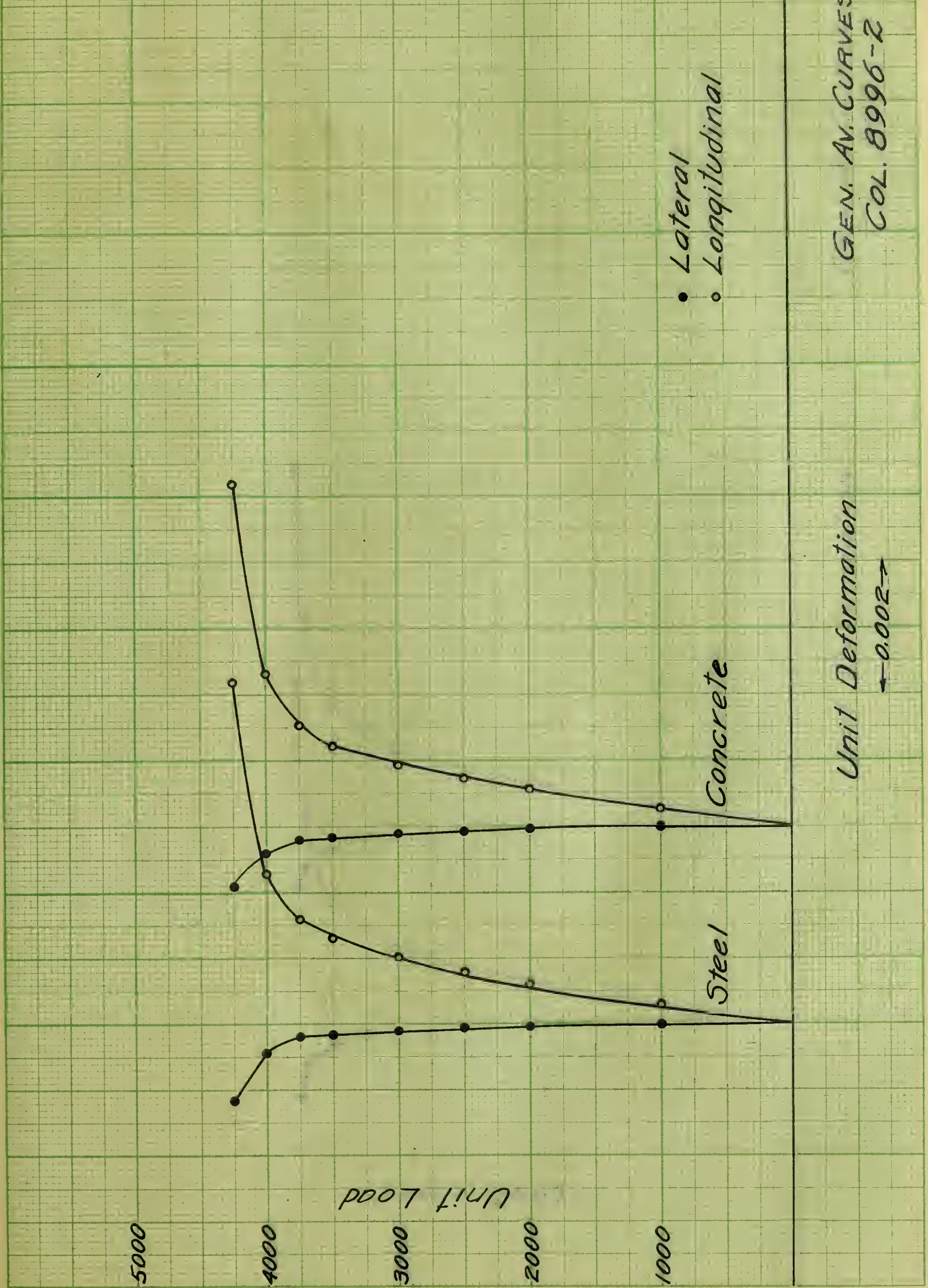


GEN. AV. CURVES
COL. 8995-3


GEN. AV. CURVES
COL. 8996-1
• Lateral
○ Longitudinal
Concrete
Steel
Unit Deformations
←0.002→
Unit Load
5000
4000
3000
2000
1000

a

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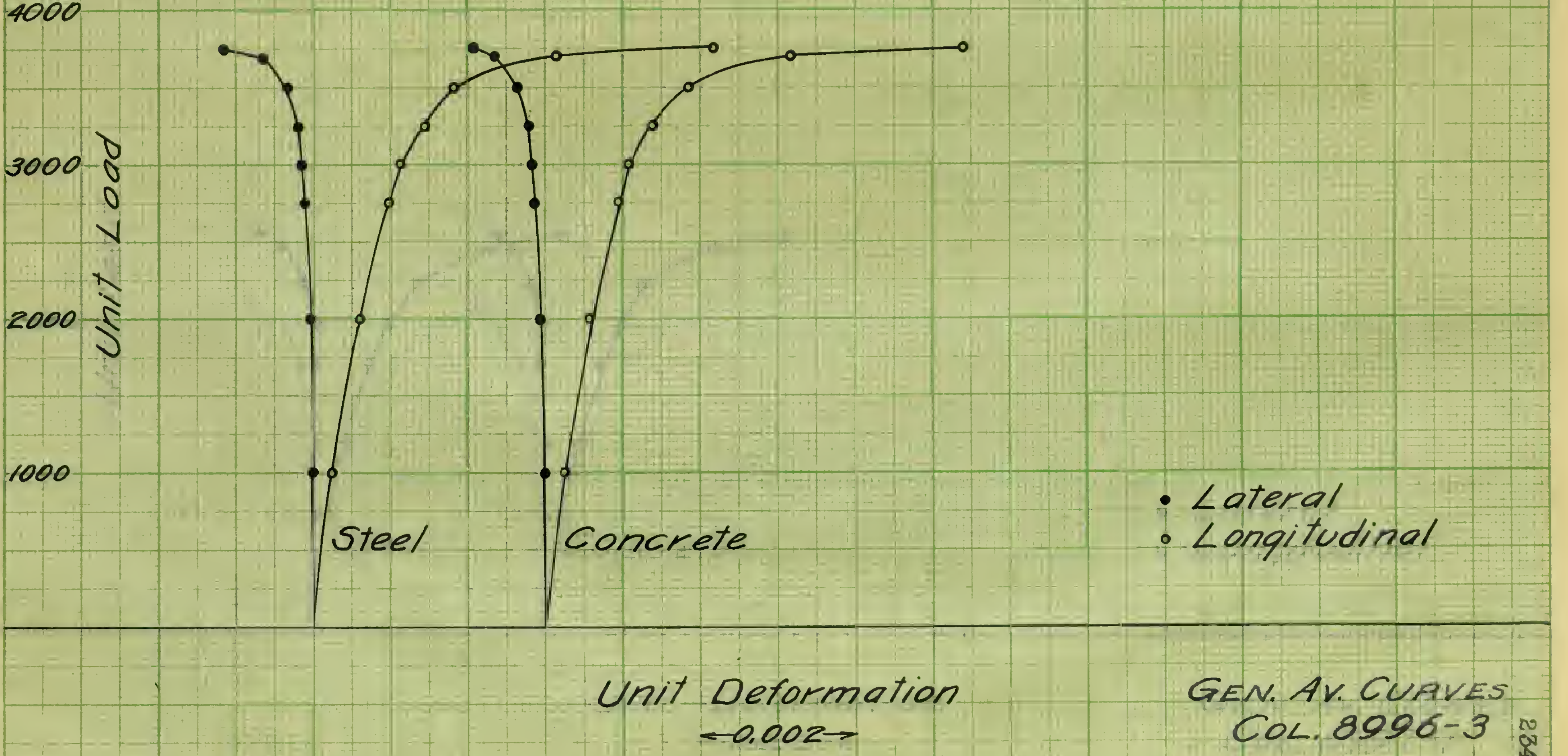
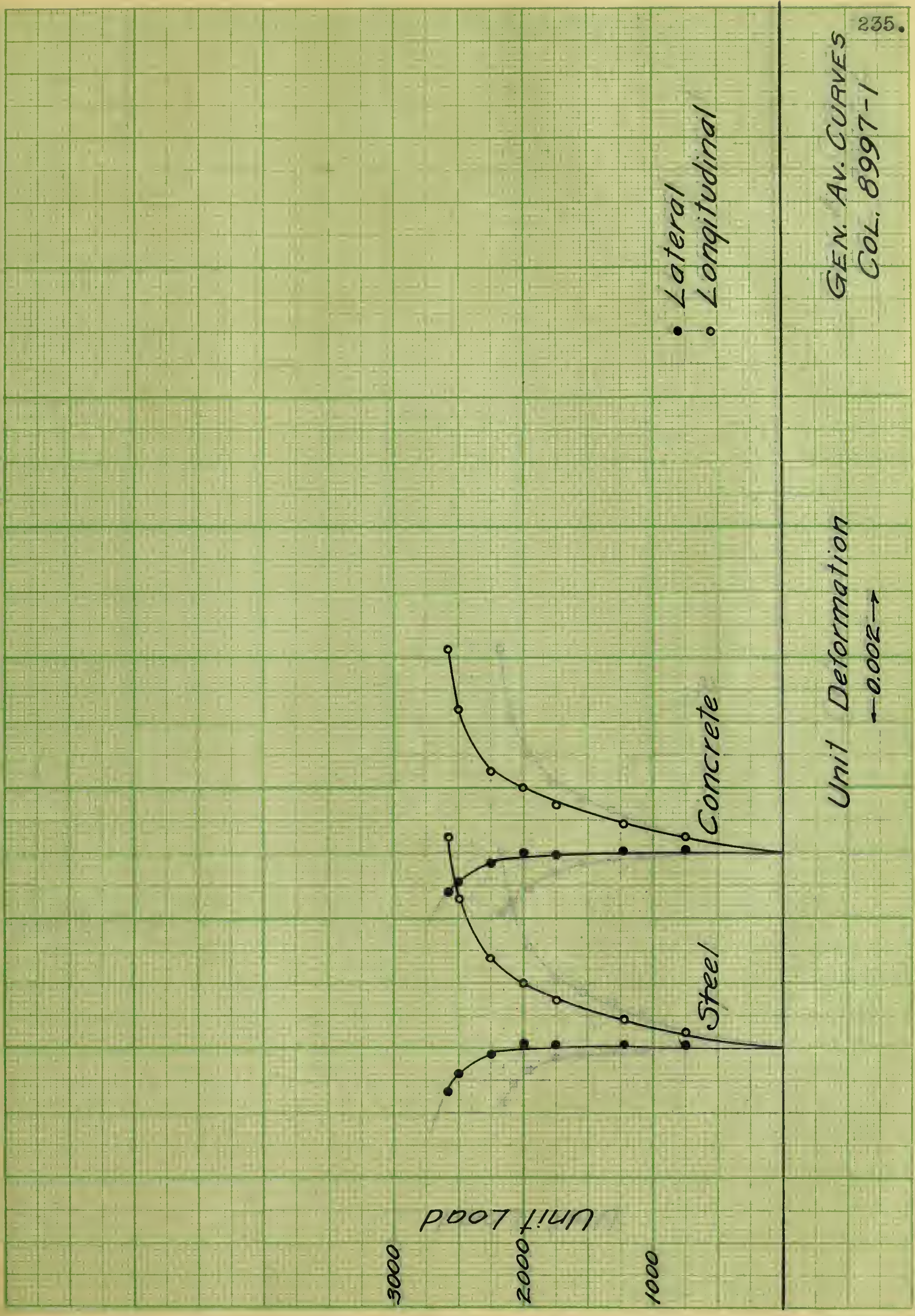
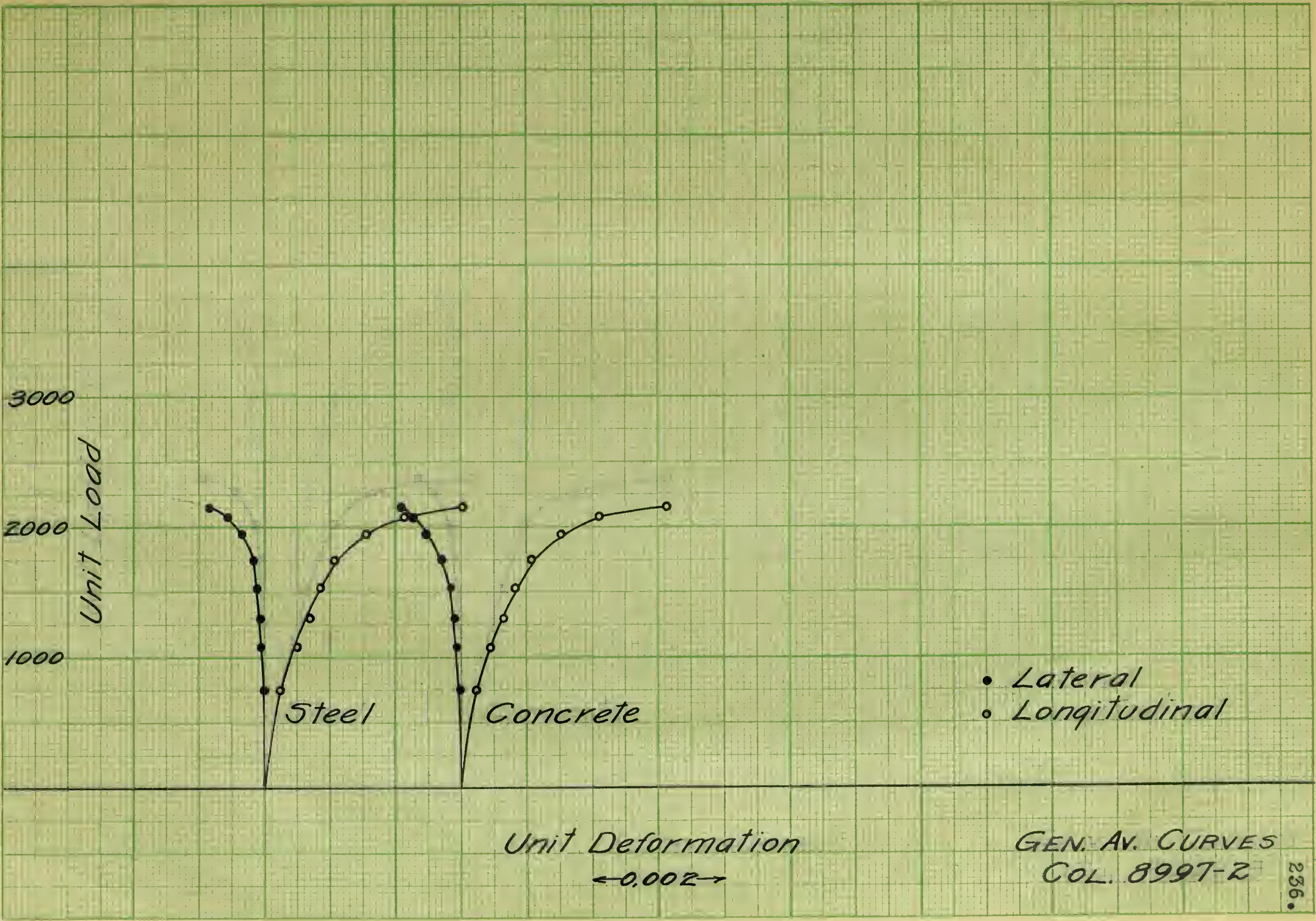
COL. 8996-2

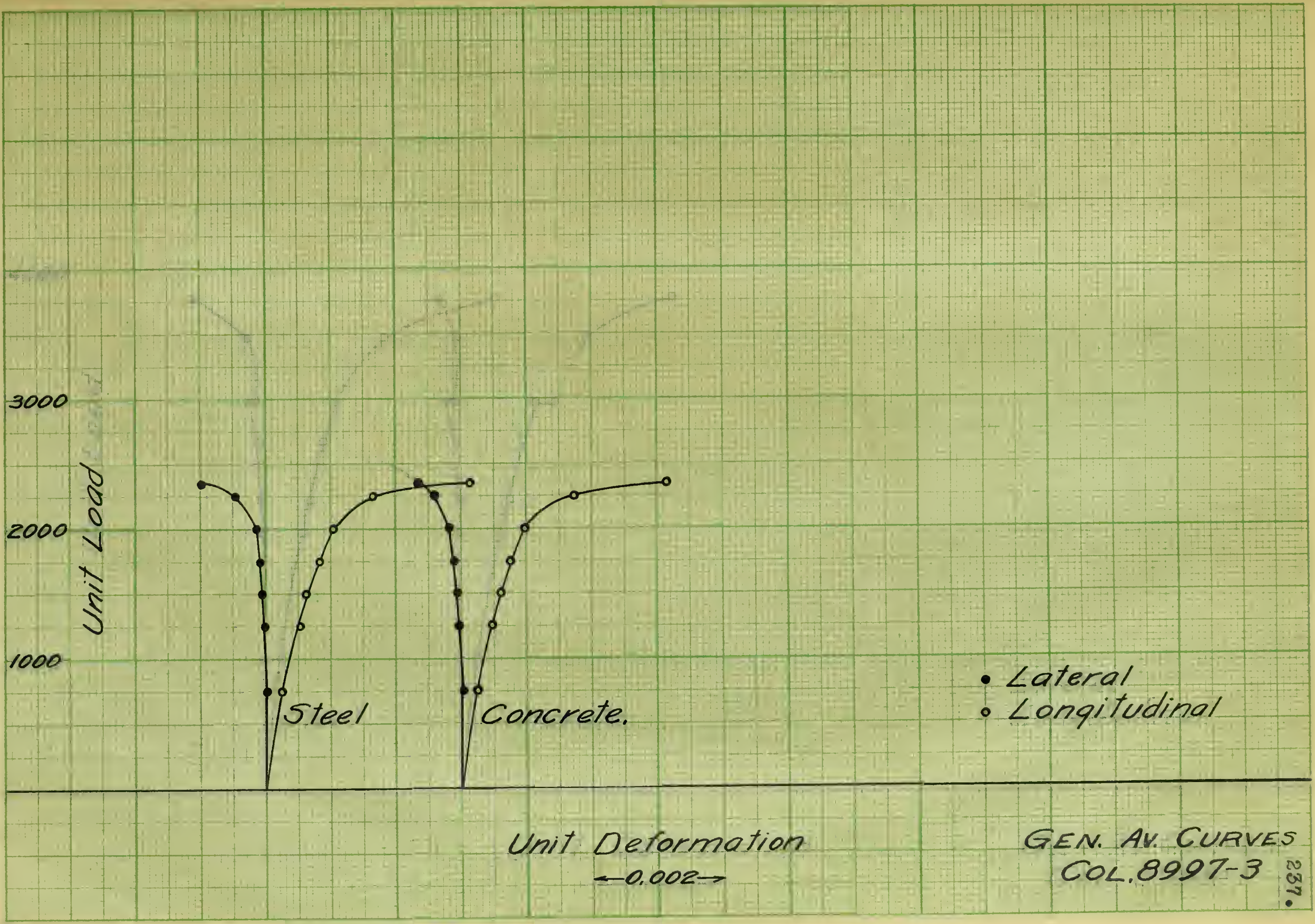


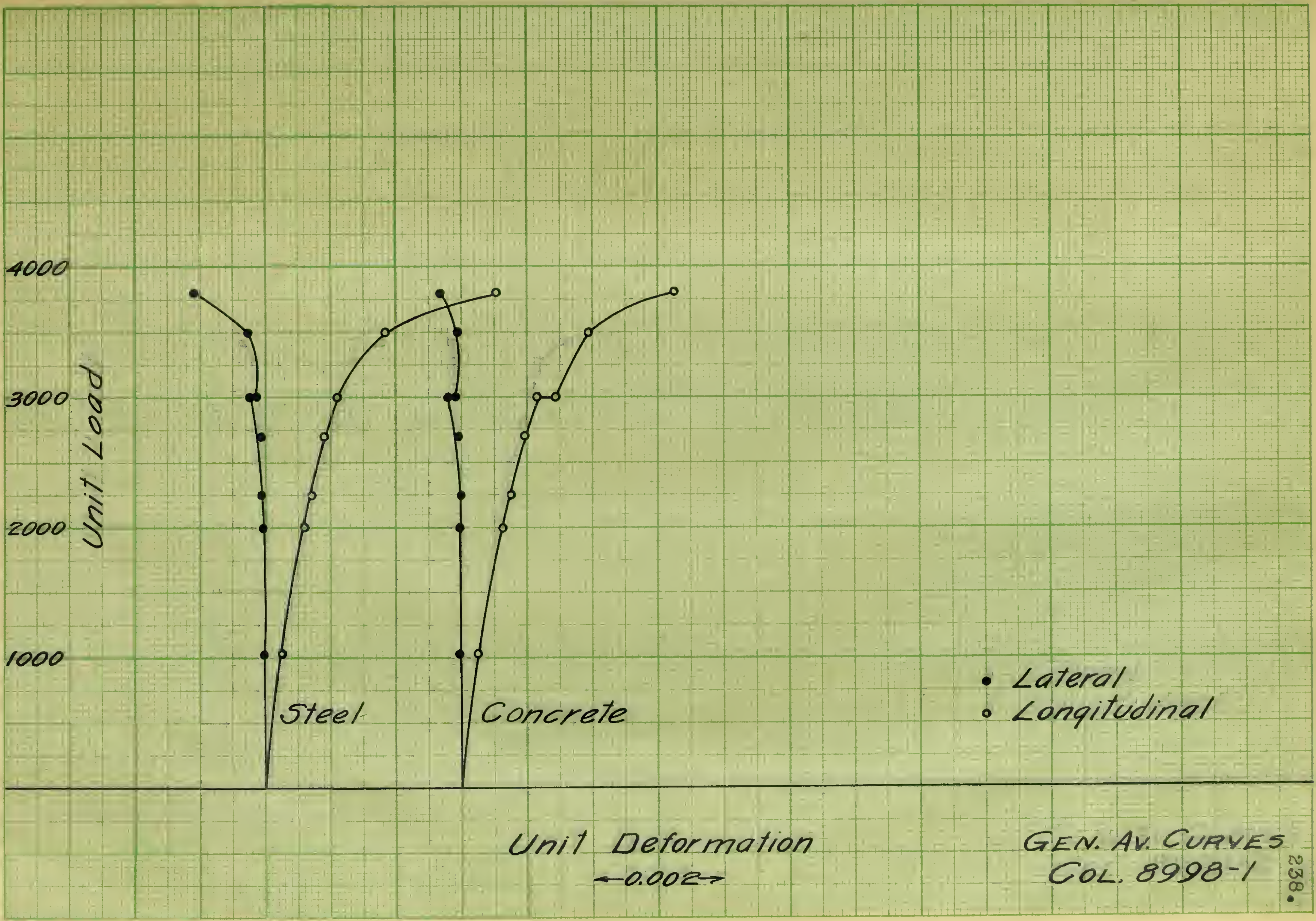
GEN. AV. CURVES
COL. 8996-3



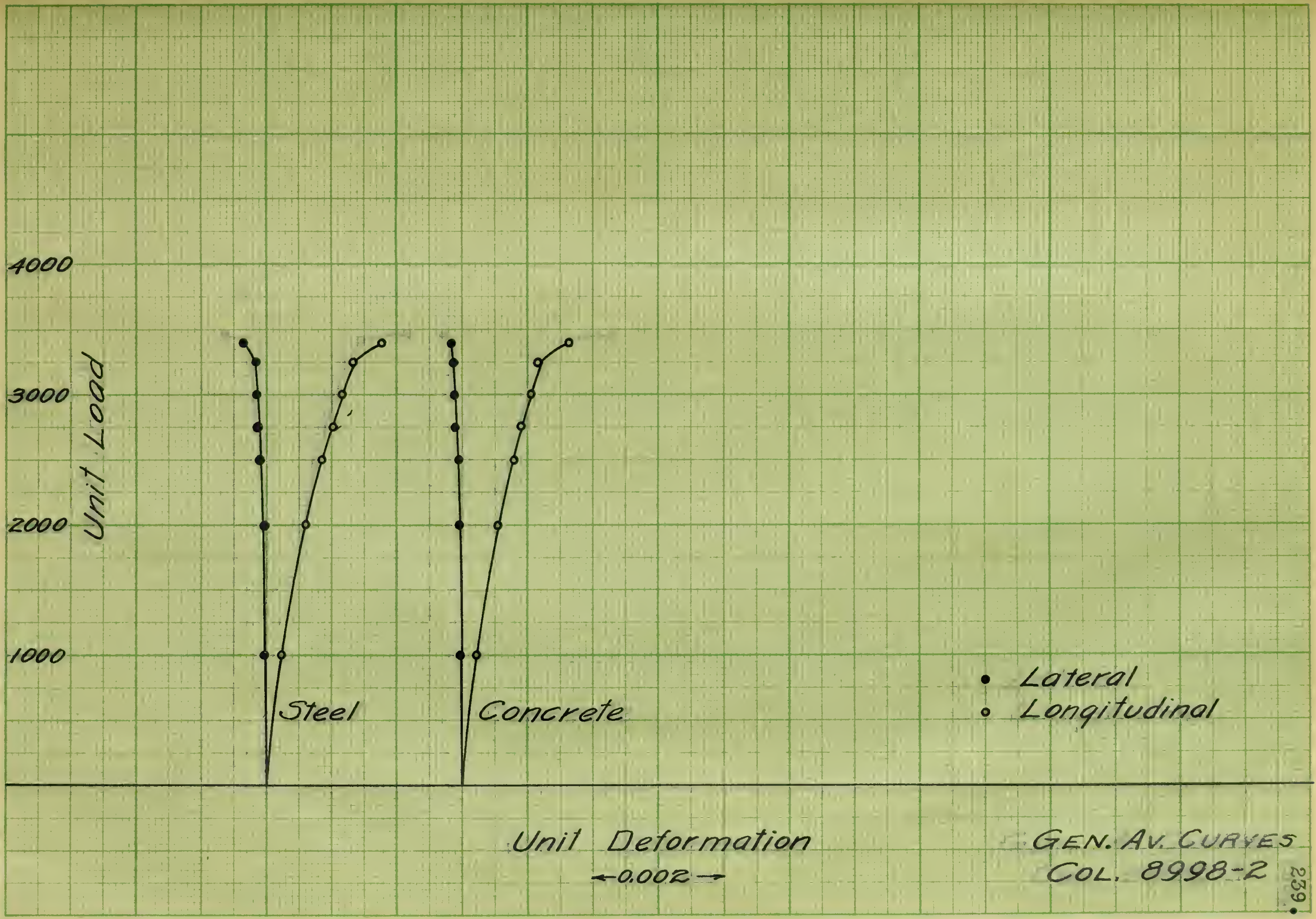
GEN. AV. CURVES
COL. 8997-1

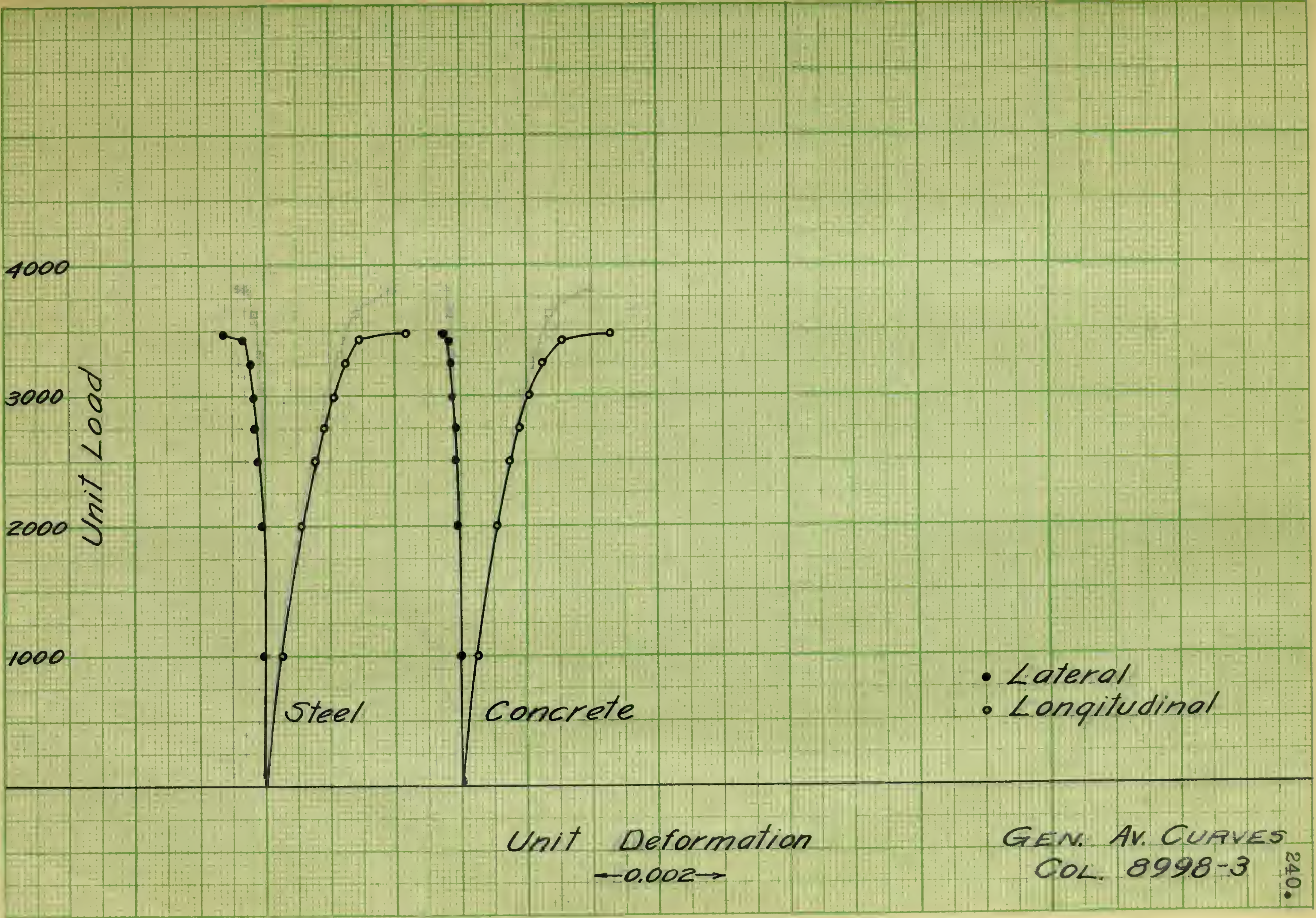

3000
2000
1000
Unit Load
Steel
Concrete
• Lateral
○ Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8997-2

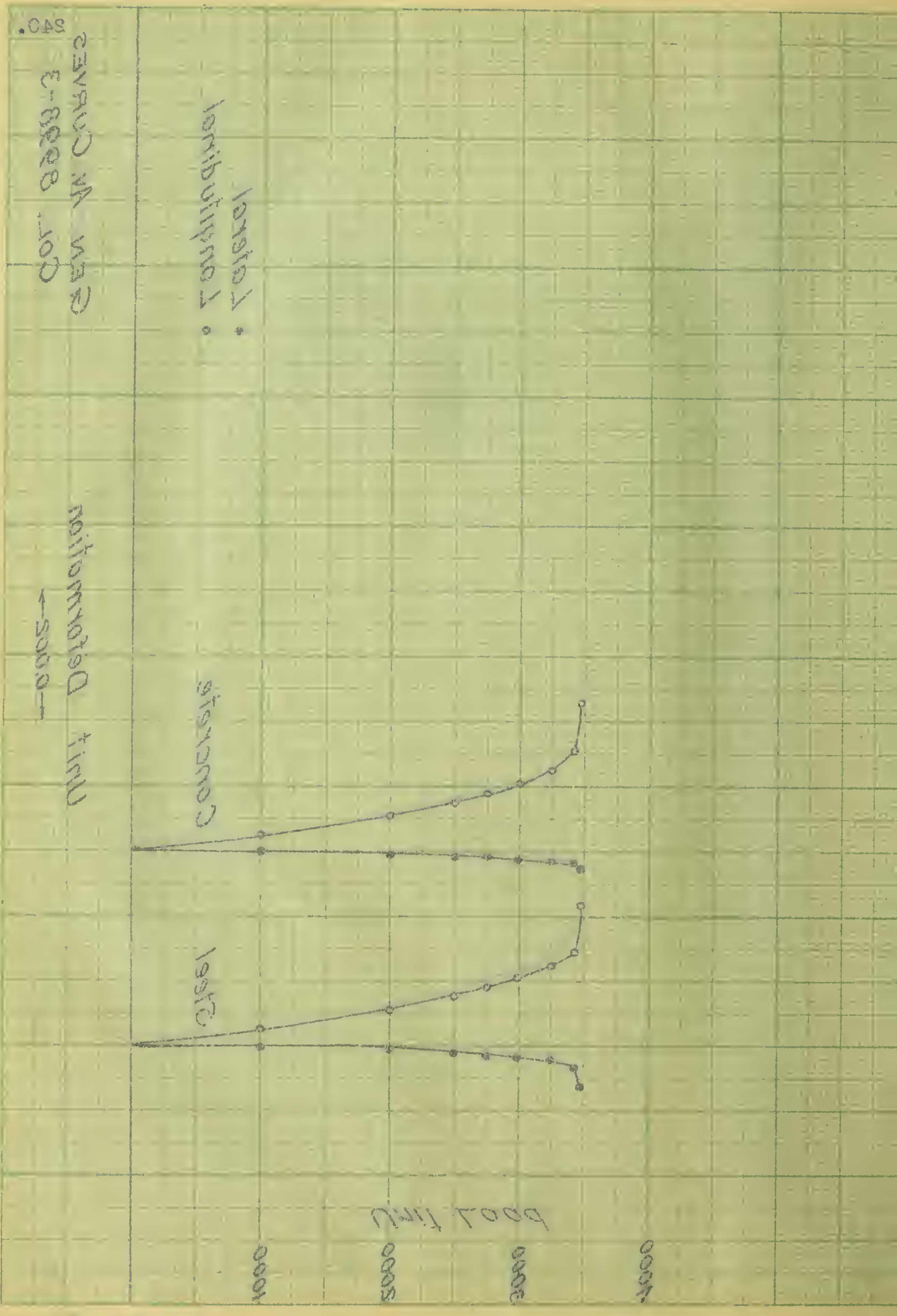

3000
2000
1000
Unit Load
Steel
Concrete.
● Lateral
○ Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8997-3

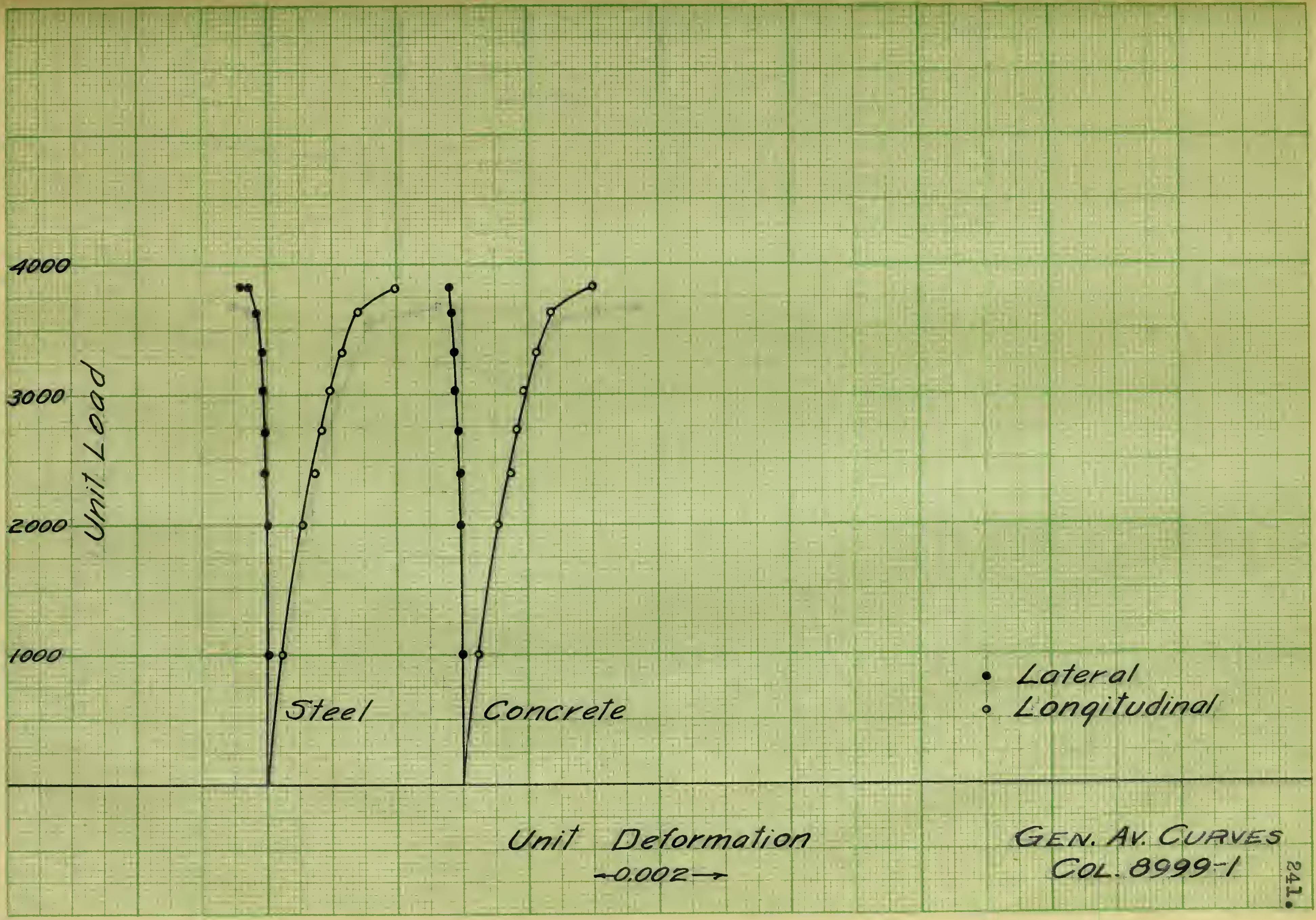


GEN. AV. CURVES
COL. 8998-1

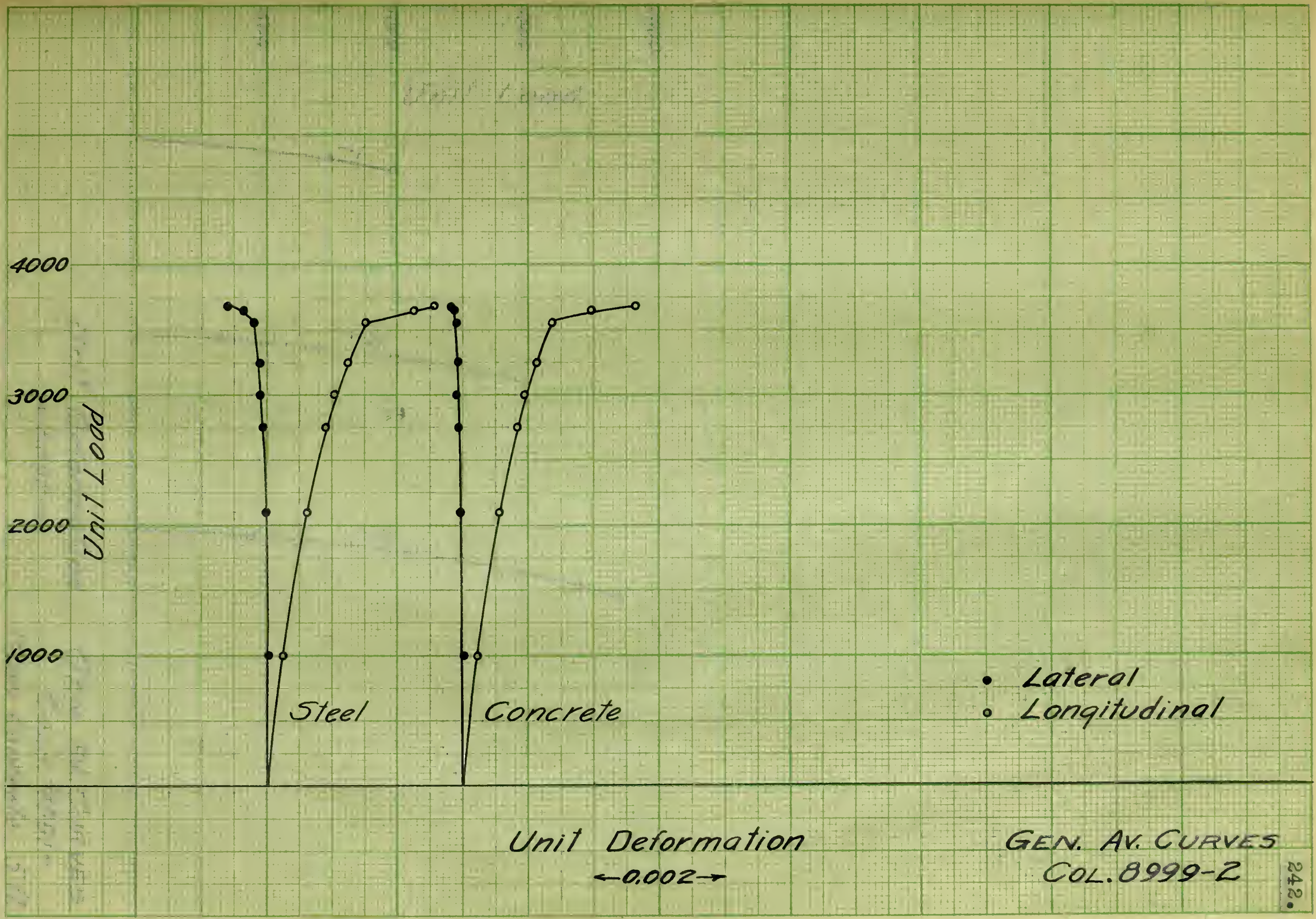

4000
3000
2000
1000
Unit Load
Steel
Concrete
● Lateral
○ Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8998-2


4000
3000
2000
1000
Unit Load
Steel
Concrete
• Lateral
◦ Longitudinal
Unit Deformation
←0.002→
GEN. AV. CURVES
COL. 8998-3

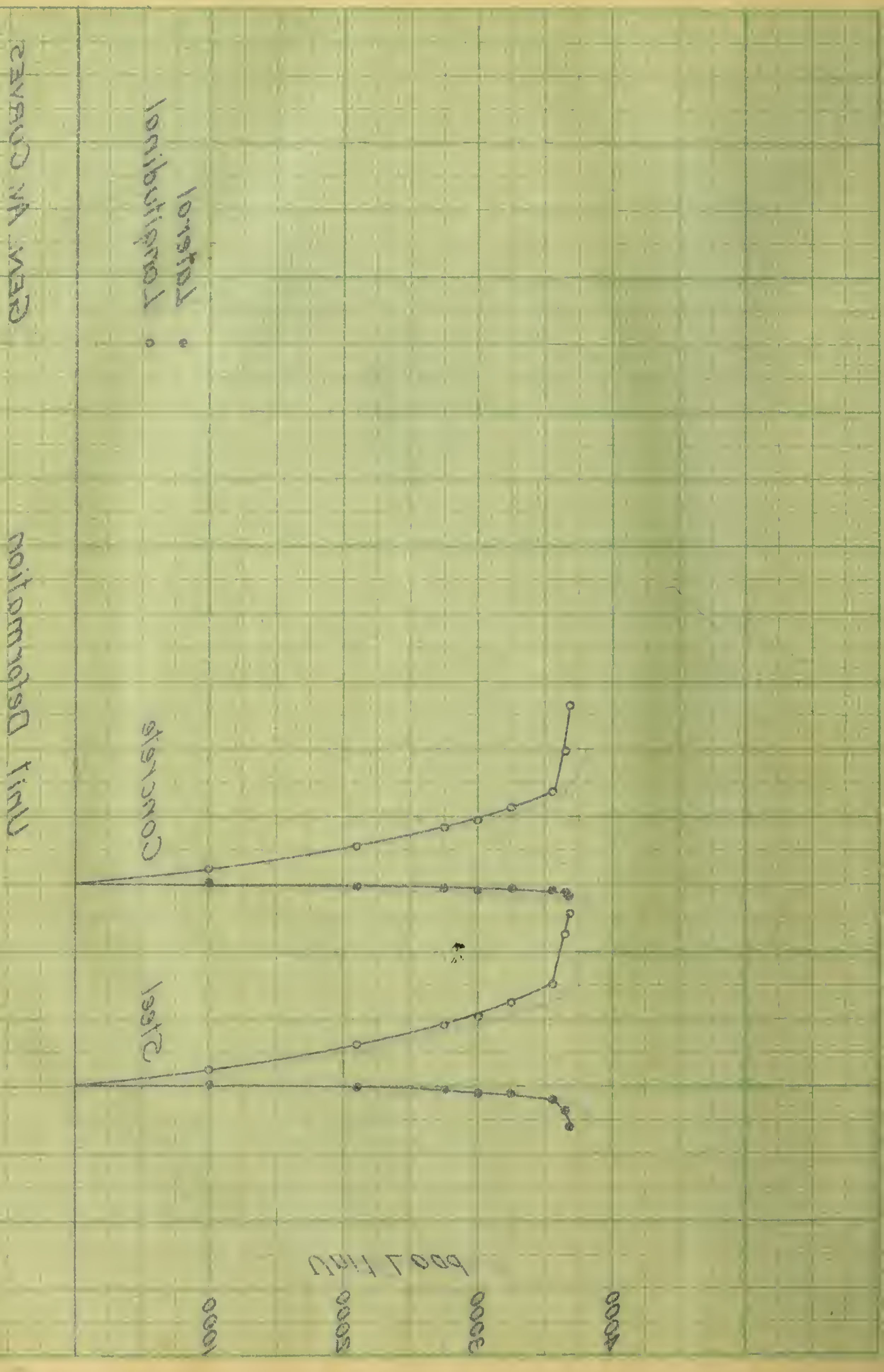

240.
Gen Av Curves
Col. 8988-3
Unit Deformation
—.0005→
• Lateral
○ Longitudinal
Concrete
Steel
Unit Load
1000
2000
3000
4000

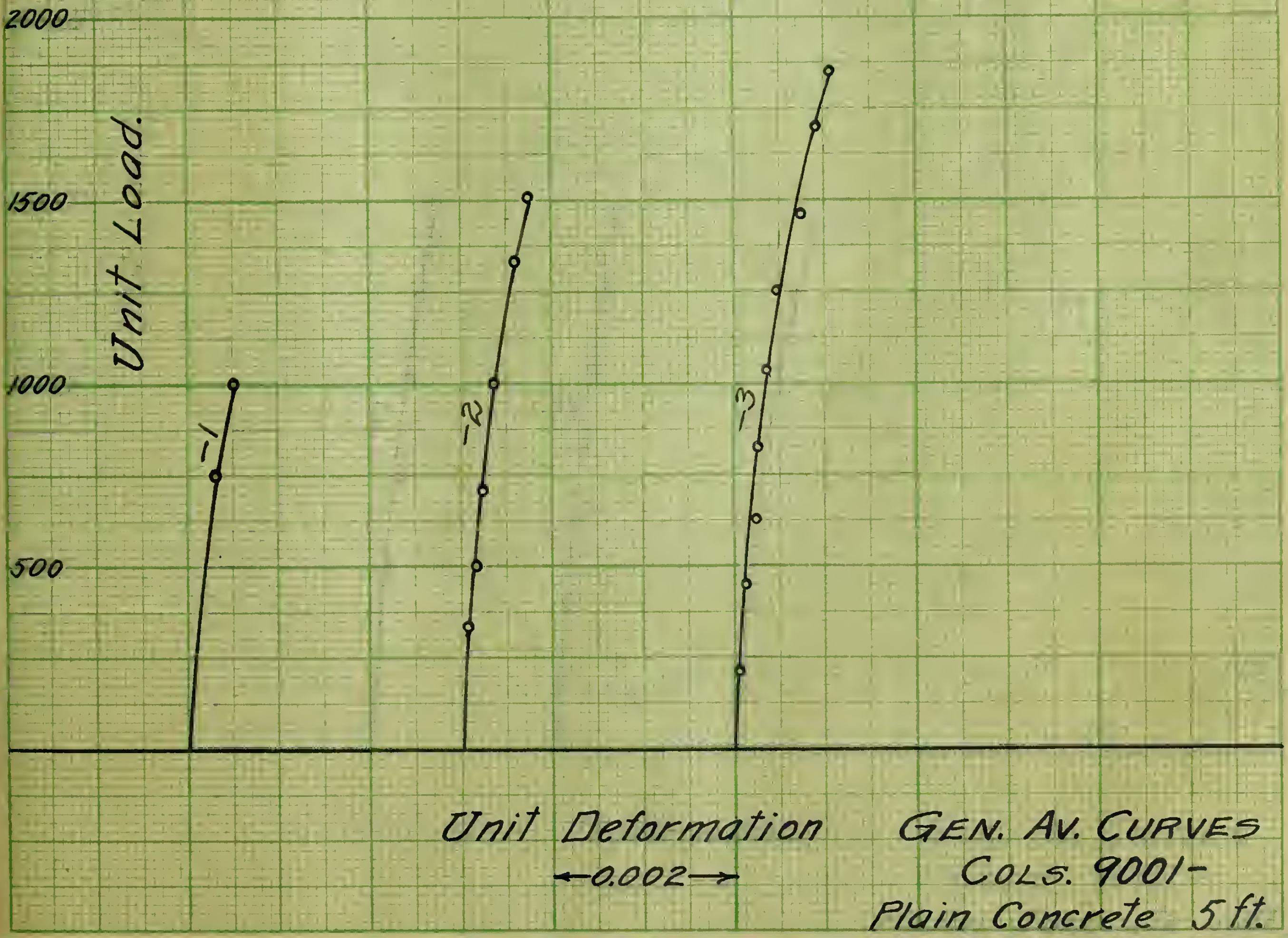


GEN. AV. CURVES
COL. 8999-1

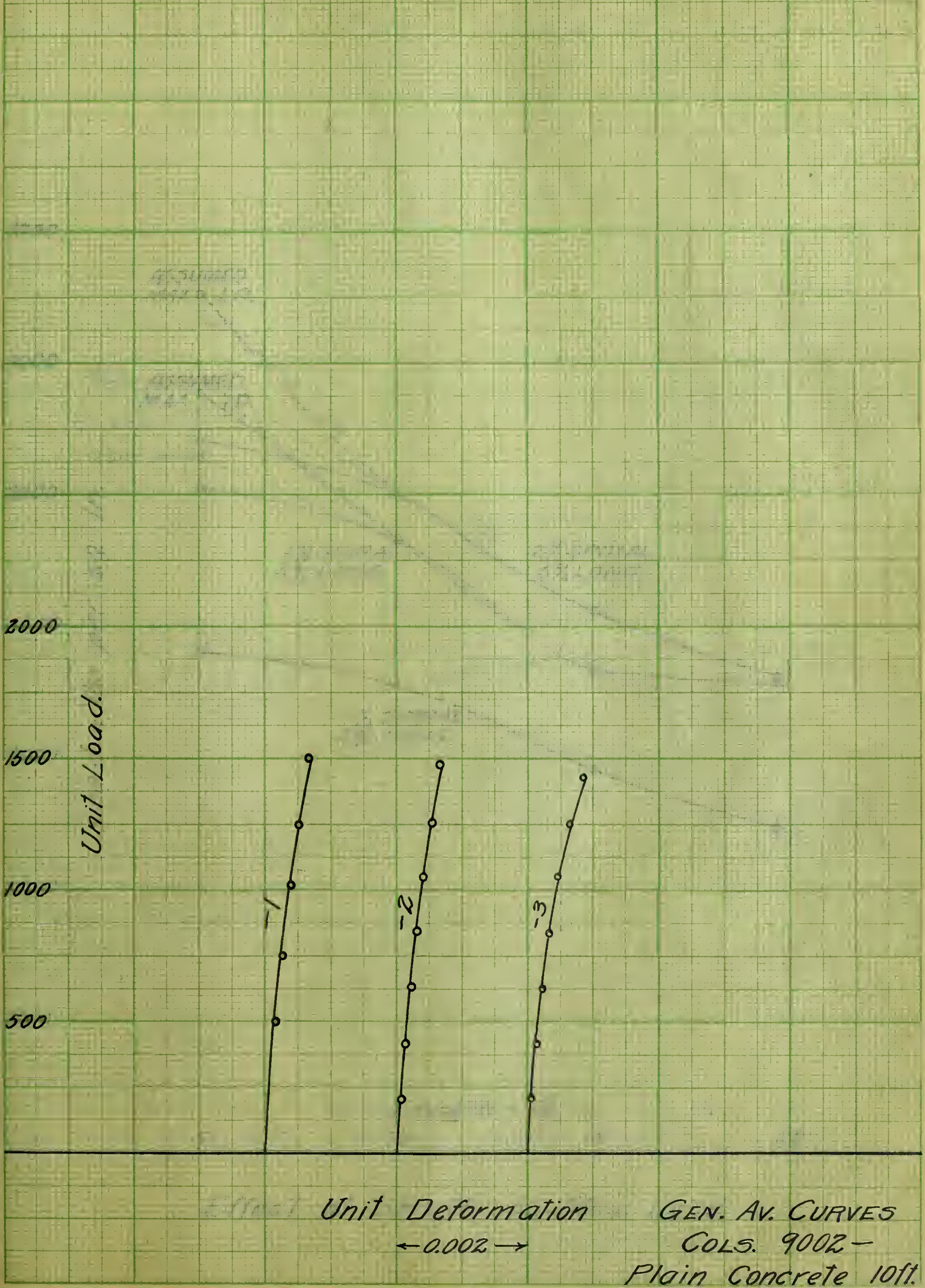


GEN. AV. CURVES
COL. 8999-2

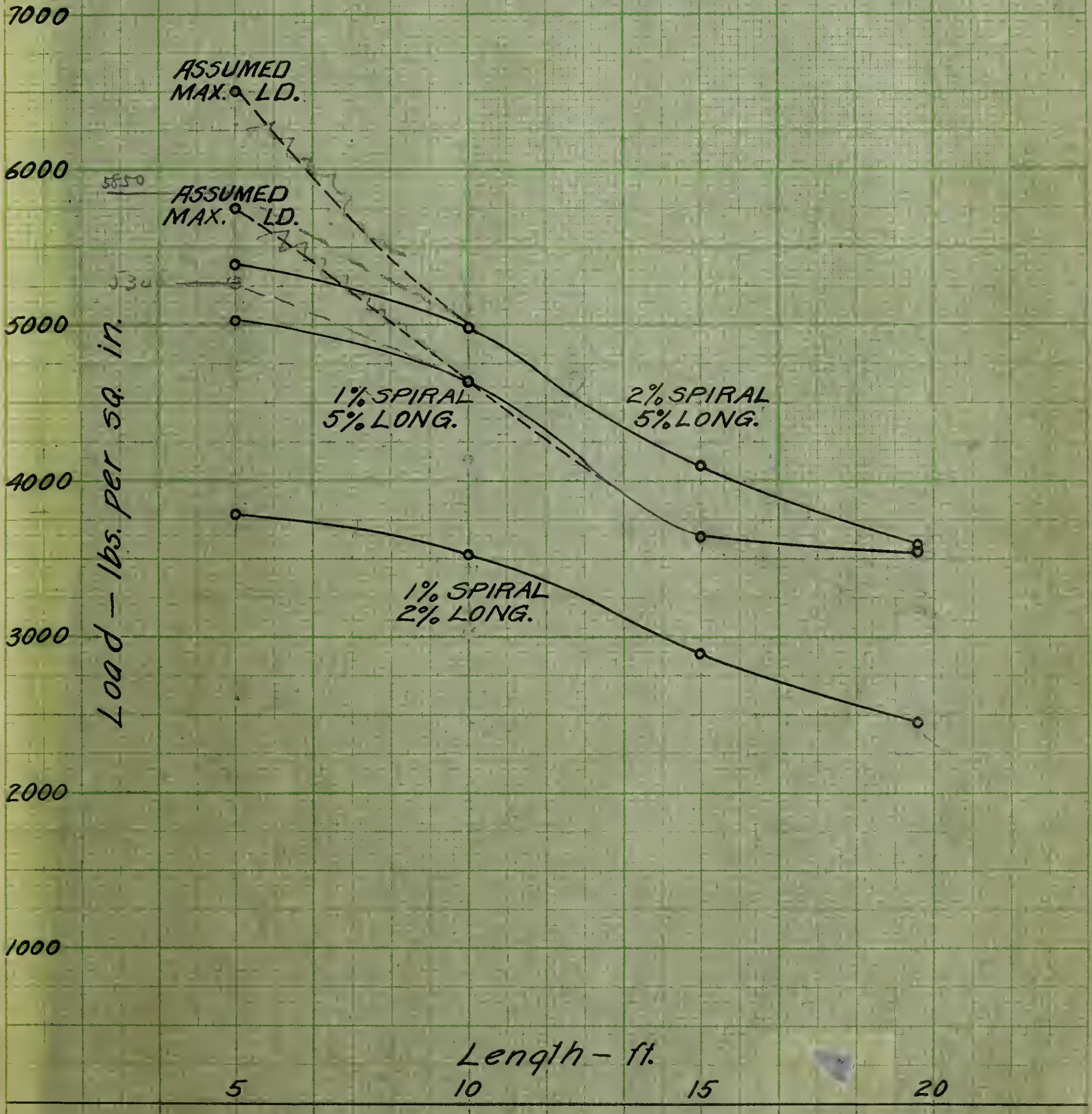

GEN. AV. CURVES
Col. 8992-2
• Lateral
○ Longitudinal
Unit Deformation
←.0002→
Concrete
Steel
Unit Load
1000
2000
3000
4000



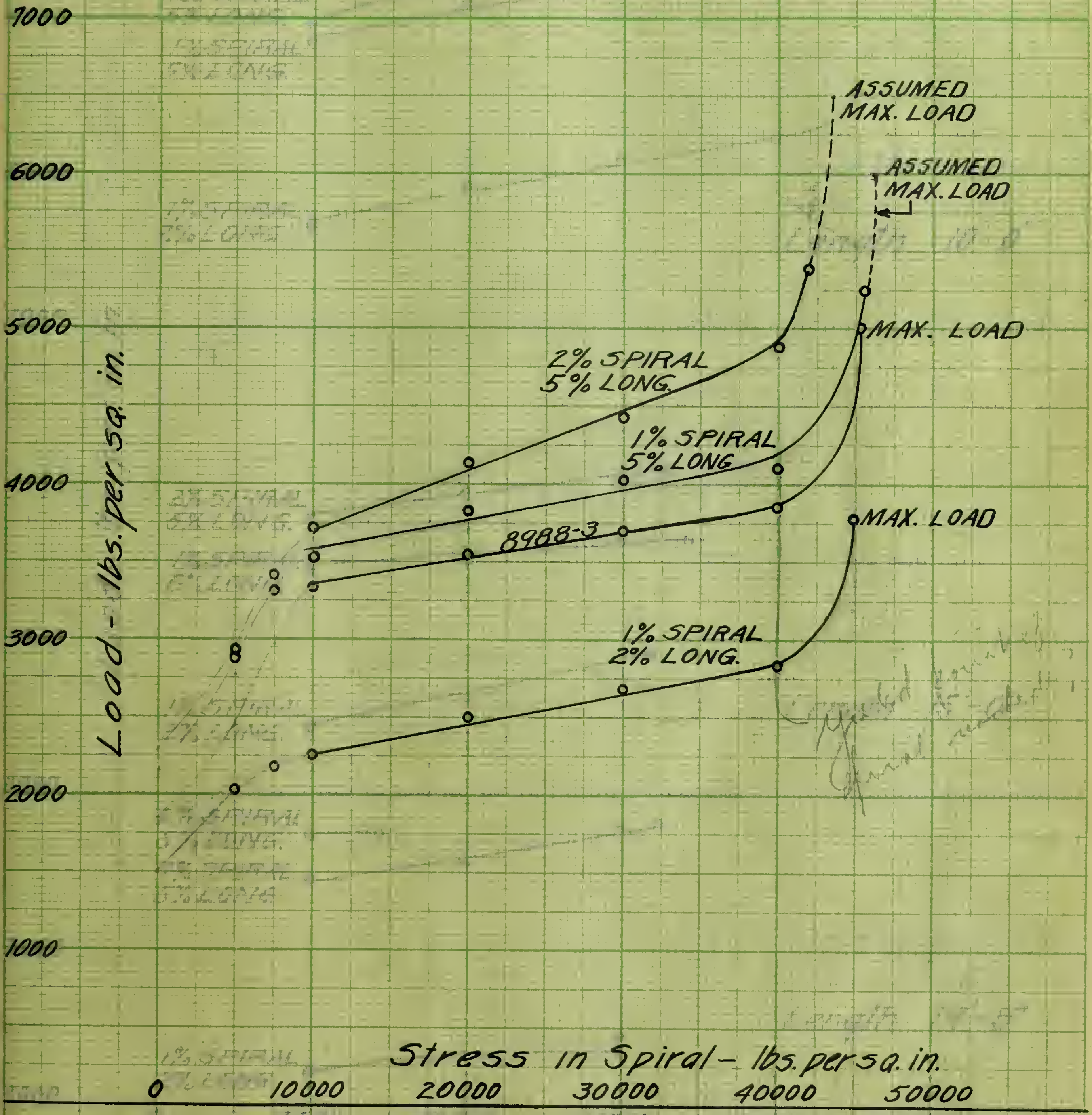
Gen. Av. Curves
Cols. 9001-
Plain Concrete 5 ft.



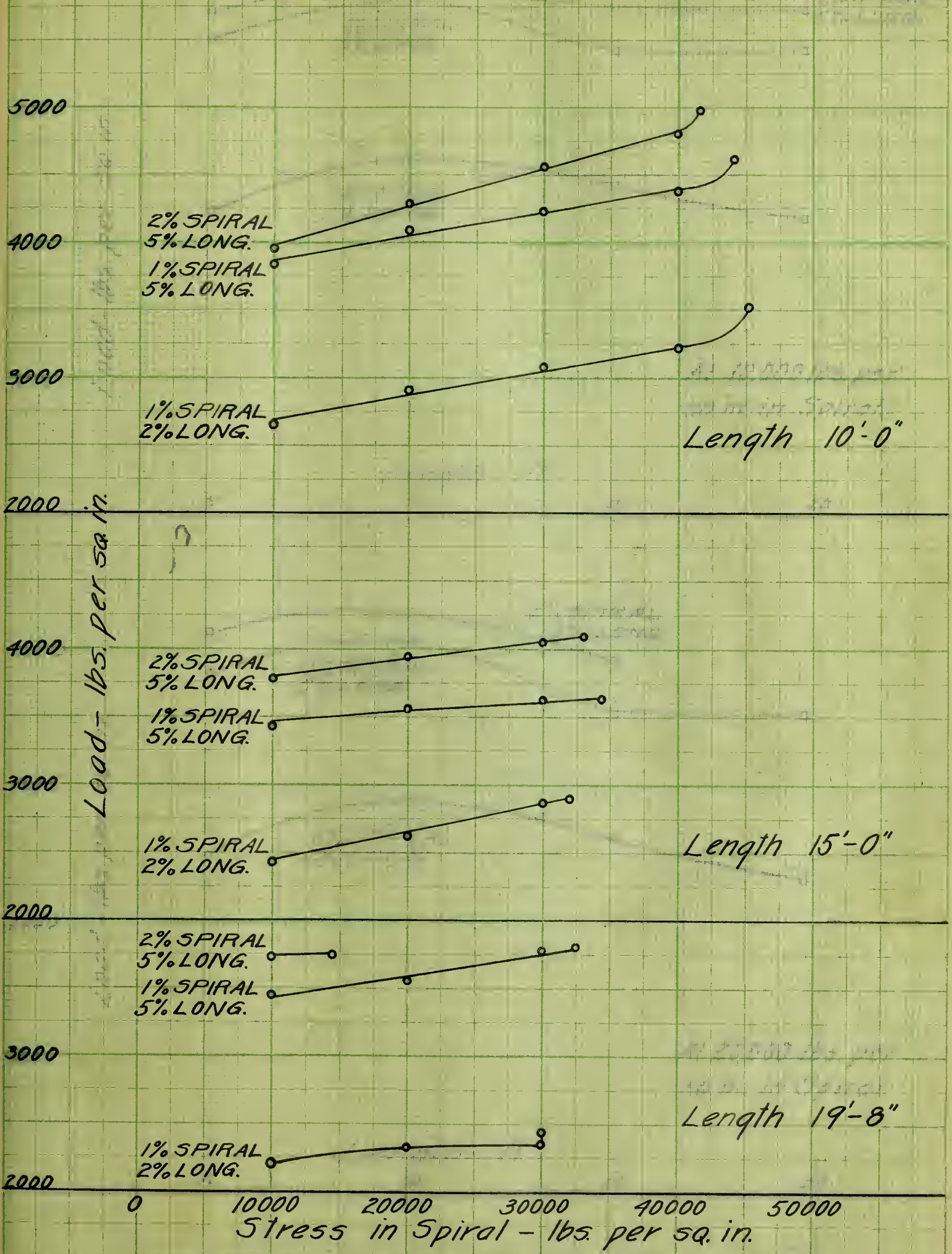
GEN. AV. CURVES
COLS. 9002—
Plain Concrete 1011.



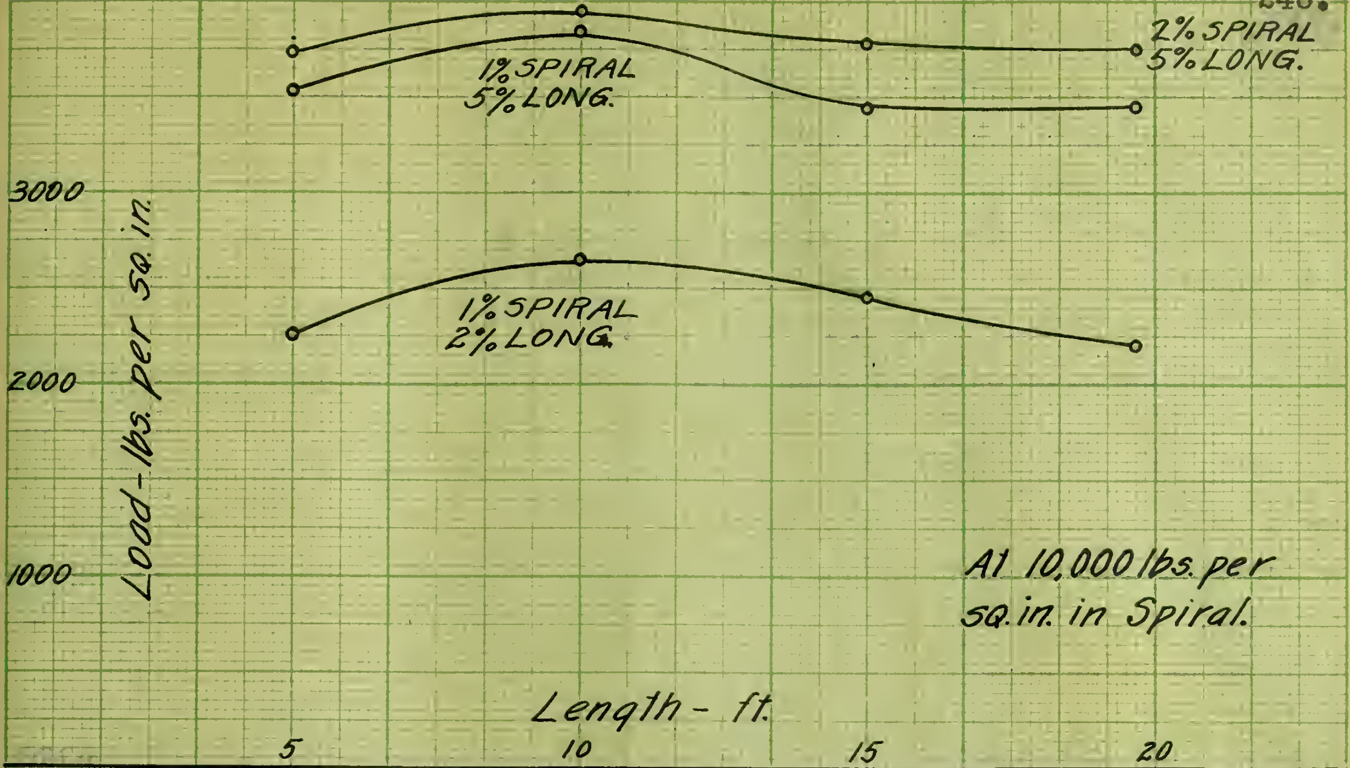
Effect of Length on Max. Load.

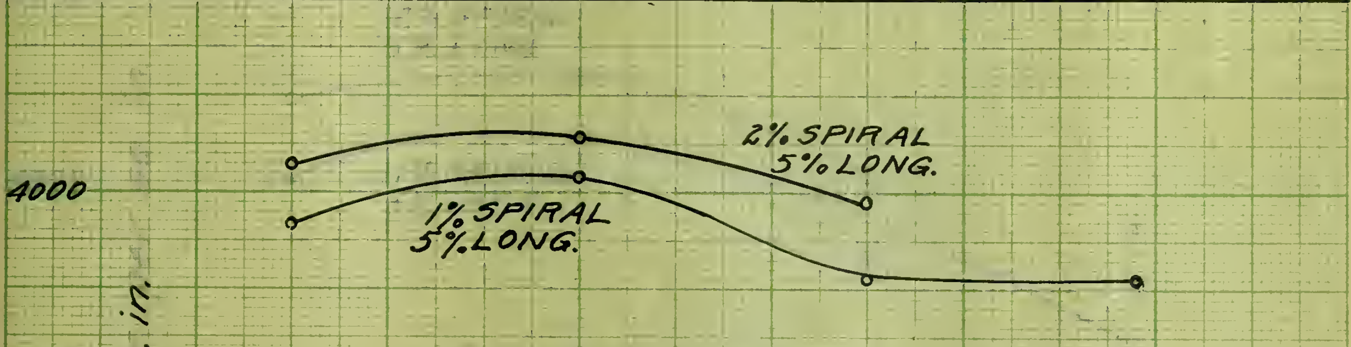


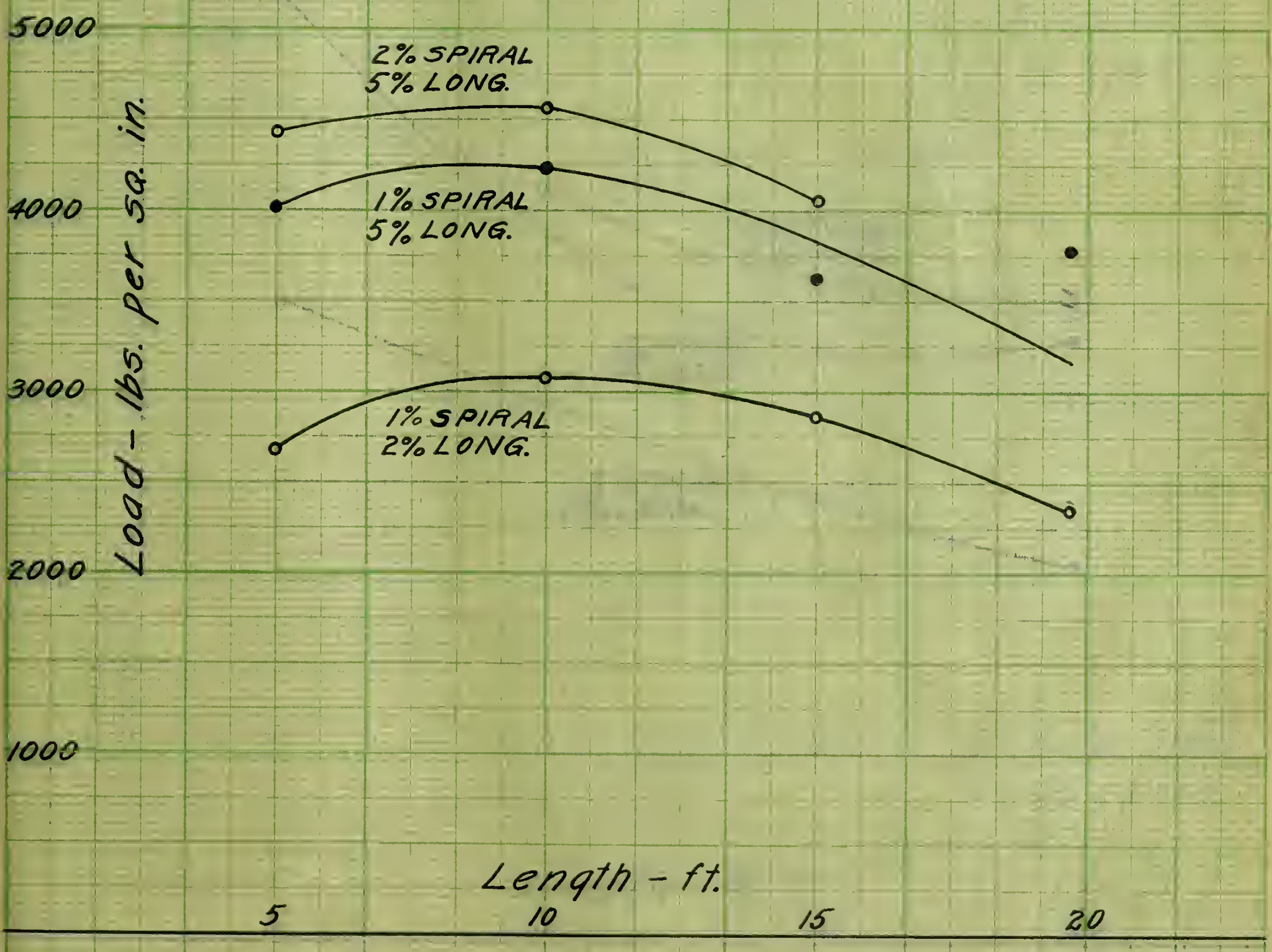
Av. Load-Stress Curves for Spiral in 5 ft. Columns.



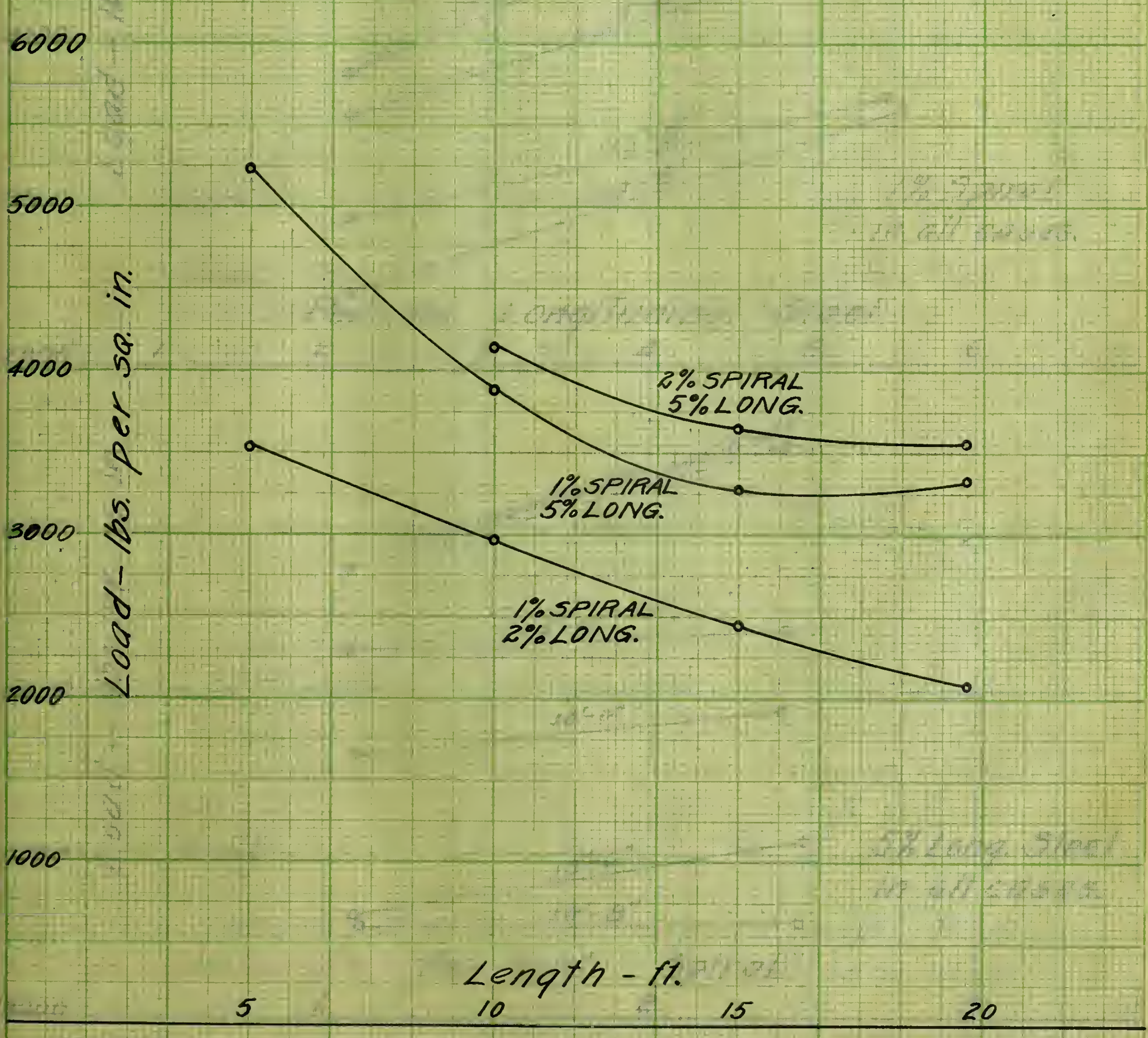
Av. Load - Stress Curves for Spiral.


2% SPIRAL
5% LONG.
1% SPIRAL
5% LONG.
1% SPIRAL
2% LONG.
3000
2000
1000
Load - lbs. per sq. in.
At 10,000 lbs. per sq. in. in Spiral.
Length - ft.
5
10
15
20

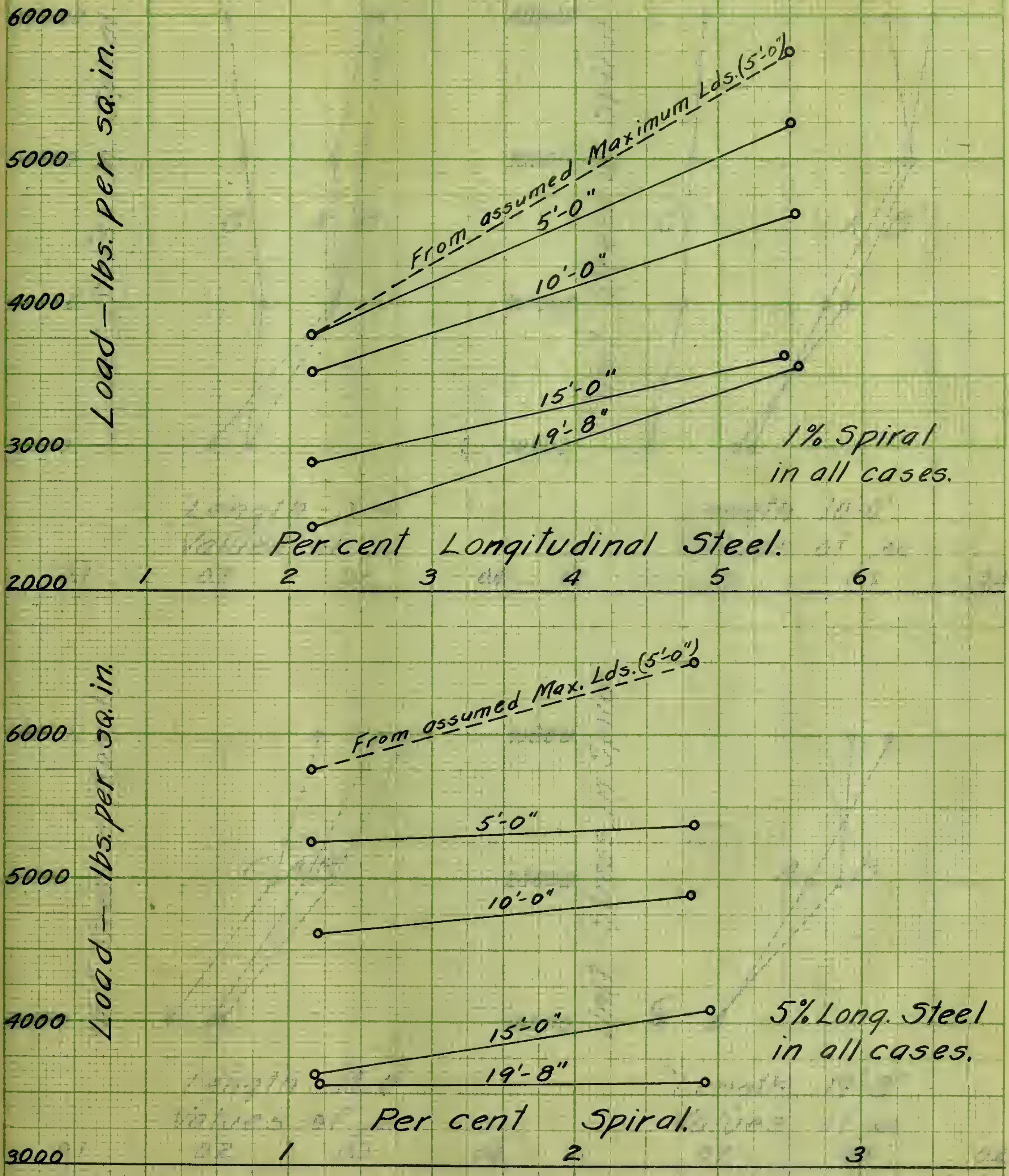

2% SPIRAL
5% LONG.
1% SPIRAL
5% LONG.
1% SPIRAL
2% LONG.
4000
3000
2000
1000
Load - lbs. per sq. in.
At 20,000 lbs. per sq. in. in Spiral.
Length - ft.
5
10
15
20



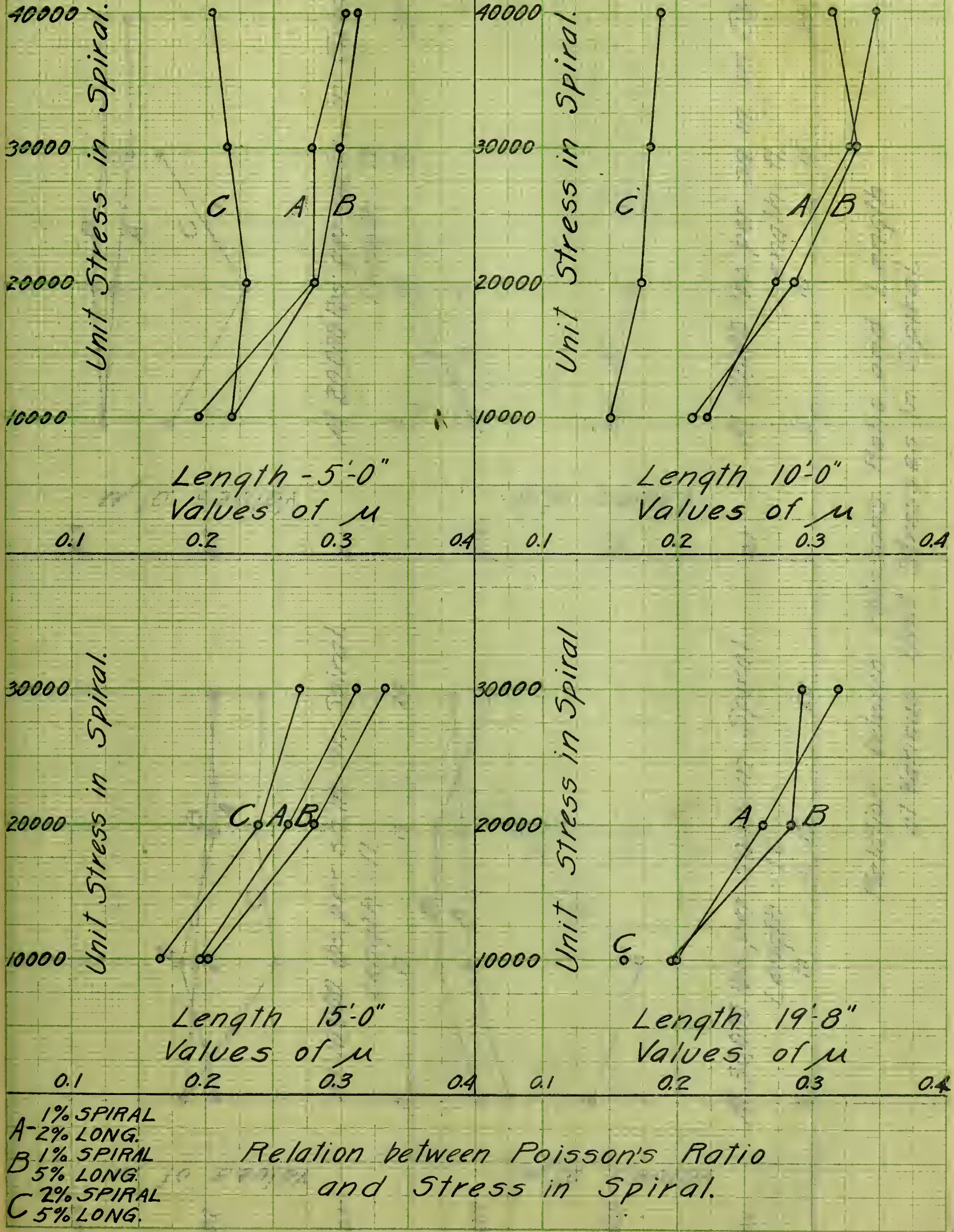
Unit Load necessary to produce a Stress of 30,000 lbs. per sq. in. in Spiral.



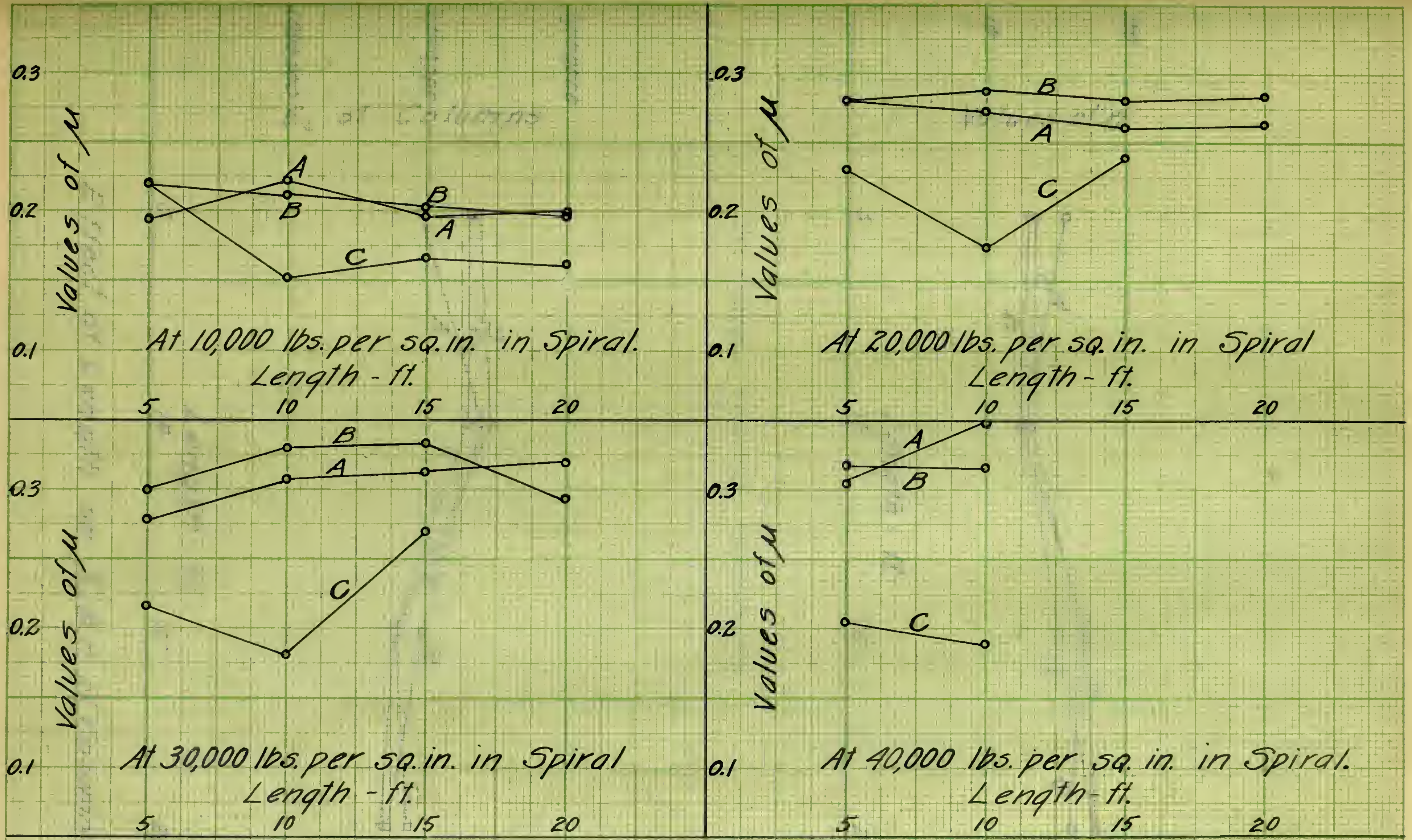
Load necessary to produce a
Deflection of 0.1 in.



Effect of Longitudinal and Spiral Reinforcement on Maximum Load.



Relation between Poisson's Ratio and Stress in Spiral.

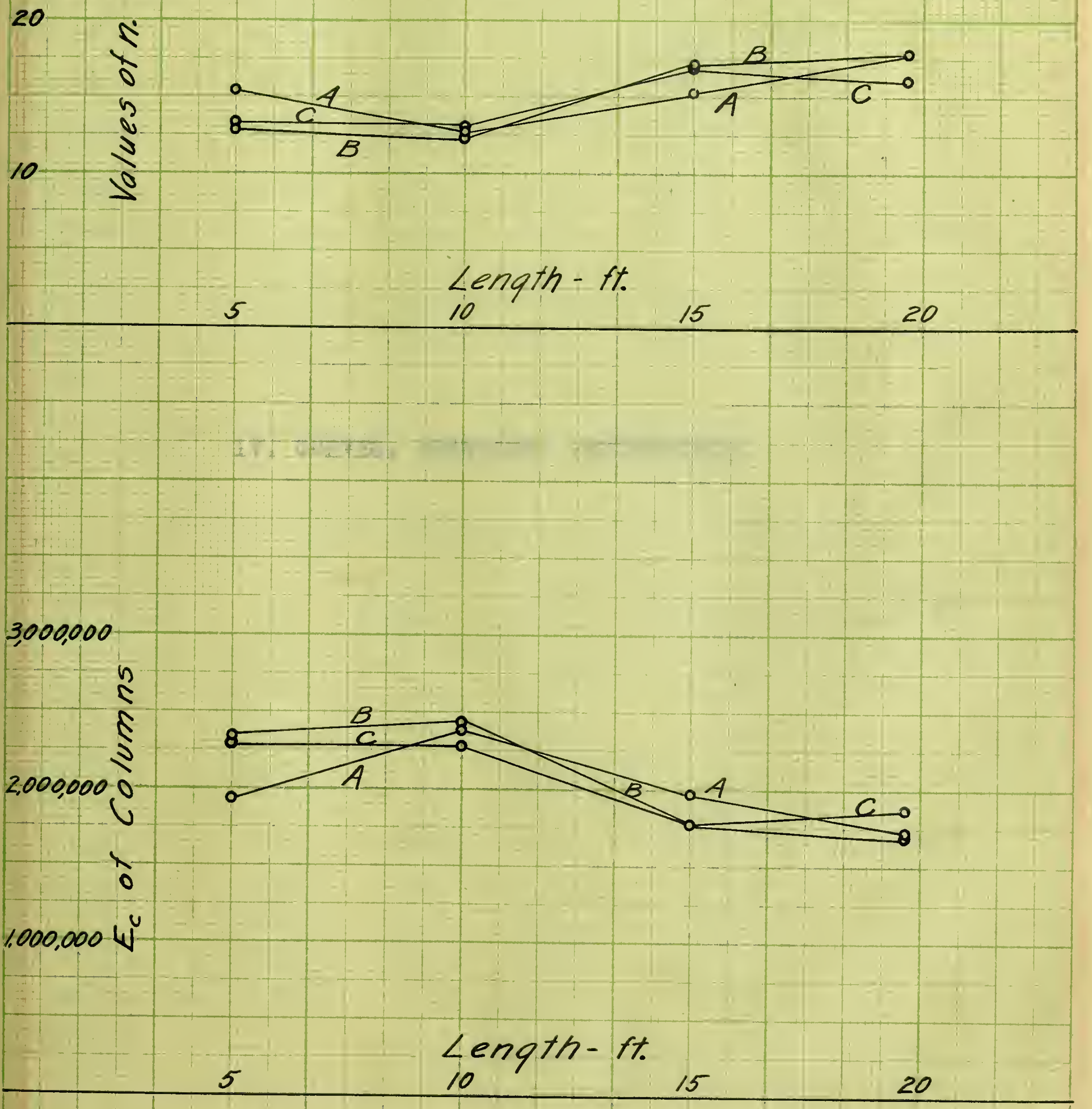

At 10,000 lbs. per sq. in. in Spiral.

At 20,000 lbs. per sq. in. in Spiral

At 30,000 lbs. per sq. in. in Spiral

At 40,000 lbs. per sq. in. in Spiral.

Relation between Poisson's Ratio and Length at Various Unit Stresses in Spiral.



Effect of Length on E_c & n of Columns.

IV. CURVES, DRAWINGS, PHOTOGRAPHS.

COLUMN NO. 8986-1

Average Unit Deformations in thousandths on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
1000	0.392	0.296	0.283	0.380	0.377	0.408
1595	0.607	0.642	0.788	0.855	0.877	0.924
2000	0.863	0.909	1.250	1.334	1.701	1.788
2240	1.251	1.261	2.448	2.587	3.160	3.348
2490	1.880	1.815	3.807	4.031	4.712	4.987
3000	5.080	4.931	8.517	8.475	9.305	9.830
3370	9.100	8.760	13.492	13.371	14.775	15.012
3790			Maximun Load.			

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection
1000	-0.030	-0.063	0.017	-0.035	
1595	-0.040	0.012	0.075	0.082	
2000	-0.005	0.134	0.373	0.203	None
2240	0.055	0.566	0.801	0.588	Apparent.
2490	0.178	0.926	1.225	0.982	
3000	1.073	2.249	2.605	2.325	
3370	2.296	4.974	4.713	4.472	
3790		Maximum Load.			

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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		[illegible]			[illegible]

COLUMN NO. 8986-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
1000	0.369	0.347	0.359	0.405	0.404	0.429
1500	0.632	0.634	0.693	0.757	0.800	0.865
1760	0.764	0.797	0.881	0.972	1.067	1.159
1900	0.850	0.899	1.015	1.112	1.293	1.456
2100	0.974	1.046	1.208	1.301	1.824	2.014
2300	1.211	1.325	2.075	2.167	3.287	3.568
2500	1.750	1.903	3.129	3.282	4.685	4.930
2960	5.580	5.902	7.592	8.000	9.597	10.212
3395	13.990	15.095	16.595	17.342	18.507	19.050
3630			Maximum Load.			

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection N.	Deflection E.
1000	-0.036	0.009	-0.020	0.063		
1500	0.010	0.018	-0.010	0.055		
1760	0.022	0.061	0.071	0.106		
1900	0.050	0.093	0.118	0.125		
2100	0.126	0.147	0.395	0.178		
2300	0.220	0.550	0.780	0.631		
2500	0.526	0.910	1.233	0.932		
2960	1.946	2.248	2.772	2.167	0	0
3395	4.682	5.455	5.786	3.696	0.03	0.12
3630		Maximum Load.			0.25	0.26

COLUMN NO. 8986-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.308	0.295	0.358	0.343	0.364	0.326
1470	0.503	0.494	0.635	0.602	0.514	0.522
1750	0.637	0.620	0.810	0.763	0.692	0.686
2000	0.846	0.835	1.128	1.065	0.897	0.909
2250	0.975	0.969	1.312	1.237	1.095	1.117
2505	1.301	1.228	2.284	2.152	1.558	1.455
2936	2.674	2.436	5.142	4.865	3.616	3.189
3540	8.970	8.665	13.100	12.652	9.235	9.065
3910	28.735	27.810	16.825	15.527	29.180	29.095

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel			Concrete	Deflection	
	Top	Center	Bottom	Center	S.	W.
1000	0.068	0.015	-0.009	0.018		
1470	0.136	0.019	0.009	0.043		
1750	0.146	0.087	0.027	0.051		
2000	0.155	0.150	0.095	0.120		
2250	0.205	0.246	0.111	0.230		
2505	0.305	0.678	0.278	0.697		
2936	0.878	1.515	1.328	1.500		
3540	3.345	4.526	3.856	3.841	0	0
3910	——	Maximum Load		——	0.20"	0.07"

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COLUMN NO. 8988-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
1025	0.281	0.225	0.223	0.254	0.259	0.259
2500	0.684	0.727	0.735	0.819	0.881	0.866
3500	1.172	1.165	1.264	1.352	1.452	1.530
4000	1.516	1.451	2.135	2.107	3.743	3.711
4500	3.305	3.093	5.613	5.341	7.669	7.617
5110	10.625	10.580	14.427	14.480	15.570	15.867

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection
1025	0.008	0.041	0.092	-0.012	
2500	0.125	0.153	0.200	0.127	
3500	0.252	0.276	0.438	0.233	None
4000	0.360	0.715	1.230	0.635	Apparent.
4500	0.937	1.823	2.645	1.588	
5110	3.927	4.490	———	3.785	

This column exceeded the capacity of the machine.

COLUMN NO.8988~~2~~

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.245	0.247	0.254	0.256	0.245	0.261
2000	0.495	0.509	0.564	0.583	0.558	0.591
2500	0.634	0.693	0.758	0.781	0.747	0.785
3000	0.770	0.845	1.102	1.023	0.960	1.020
35000	0.987	1.100	1.268	1.282	1.263	1.409
3760	1.083	1.219	1.558	1.543	1.669	1.598
4000	1.269	1.329	2.801	2.624	2.899	2.687
4260	1.696	1.670	4.322	4.451	4.706	4.523
4750	4.100	4.160	8.747	8.917	10.097	9.880
5630		Not Maximum				

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel			Concrete	Deflection	
	Top	Center	Bottom	Center	S.	W.
1000	0.012	0.006	-0.008	0.040		
2000	0.031	0.016	0.053	0.110		
2500	0.031	0.099	0.076	0.153		
3000	0.043	0.206	0.121	0.256		
3500	0.076	0.272	0.222	0.310		
3760	0.066	0.398	0.380	0.375		
4000	0.113	1.017	0.856	0.773		
4260	0.190	1.601	1.573	1.325		
4750	1.180	3.455	3.318	2.940		
5630		Not Maximum			0.03"	0.18"

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COLUMN NO. 8988-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.207	0.219	0.226	0.237	0.189	0.216
2000	0.666	0.540	0.572	0.601	0.560	0.622
2500	0.707	0.749	0.801	0.835	0.807	0.862
3000	0.929	0.978	1.042	1.093	1.066	1.149
3500	1.441	1.377	2.375	2.314	2.859	3.060
3750	2.491	2.559	4.637	4.511	5.192	5.344
4000	5.195	5.245	7.680	7.277	8.247	8.332
4250	9.960	9.721	12.130	11.680	12.525	12.675
4765	23.932	23.462	21.576	21.877	23.422	23.622
5010			Maximum Load.			

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq.in.	Steel			Concrete	
	Top	Center	Bottom	Center	Deflection
1000	0.018	0.046	0.020	0.013	
2000	0.035	0.112	0.056	0.040	
2500	0.090	0.153	0.107	0.076	
3000	0.120	0.240	0.193	0.160	
3500	0.215	0.763	0.762	0.556	
3750	0.686	1.459	1.432	1.287	
4000	1.648	2.221	2.358	2.111	
4250	3.205	3.978	4.600	3.590	
4765	———	7.011	5.530	6.877	
5010			Maximum Load.		

COLUMN NO. 8989-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
940	0.249	0.174	0.274	0.243	0.303	0.273
1800	0.564	0.521	0.597	0.564	0.609	0.605
2825	1.358	0.845	1.002	0.999	1.044	1.069
3300	2.034	1.031	1.337	1.269	1.365	1.425
3735	2.807	1.382	2.832	2.664	3.012	3.041
4000	3.626	1.832	4.150	4.085	4.288	4.412
4250	4.679	2.956	5.190	5.266	5.574	5.749
4710	8.950	6.715	8.567	8.187	8.682	8.770
5215	13.055	11.000	11.917	11.695	12.272	12.805

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel			Concrete	Deflection	
	Top	Center	Bottom	Center	W.	S.
940	0.040	0.074	-0.012	-0.027		
1800	0.081	0.139	-0.070	-0.052		
2825	0.359	0.284	0.113	0.107		
3300	0.457	0.363	0.171	0.202		
3735	0.740	0.694	0.511	0.537		
4000	0.835	0.899	0.761	0.756		
4250	1.177	1.134	0.983	1.021	0	0
4710	1.822	1.595	1.446	1.621	0	0
5215	3.212	2.484	2.345	2.426	0.05"	0.06"

This column exceeded the capacity of the machine.

COLUMN NO. 8989-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
1015	0.239	0.245	0.239	0.229	0.185	0.209
1990	0.422	0.471	0.534	0.557	0.501	0.529
2500	0.594	0.668	0.747	0.768	0.706	0.748
2995	0.814	0.890	0.994	1.029	0.952	1.033
3230	0.959	1.035	1.155 ~~1.655~~	1.201	1.110	1.171
3480	1.128	1.217	1.348	1.387	1.271	1.374
3720	1.236	1.320	1.460	1.494	1.421	1.557
3980	1.446	1.501	1.970	1.901	1.907	2.030
4230	2.059	2.025	3.403	3.433	3.545	3.820
4660	4.010	4.502	6.997	6.847	6.395	6.740
5550	12.320	12.747	16.720	16.302	15.560	16.307

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection
1015	0.031	0.032	0.049	0.056	
1990	0.117	0.084	0.091	0.112	
2500	0.129	0.116	0.119	0.151	
2995	0.175	0.133	0.152	0.151	
3230	0.189	0.141	0.149	0.167	None
3480	0.181	0.201	0.161	0.186	Apparent.
3720	0.211	0.222	0.210	0.212	
3980	0.242	0.392	0.315	0.295	
4230	0.381	0.788	0.837	0.692	
4660	0.912	1.398	1.342	1.396	
5550	2.539	4.205	4.037	4.106	

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COLUMN NO. 8989-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.230	0.240	0.229	0.244	0.227	0.231
1990	0.508	0.501	0.482	0.521	0.542	0.534
2980	0.859	0.922	0.885	0.946	0.969	0.973
3275	1.025	1.058	1.037	1.098	1.175	1.169
3480	1.121	1.169	1.144	1.212	1.335	1.296
3720	1.326	1.321	1.321	1.396	1.642	1.536
3975	1.805	1.817	1.947	1.948	2.593	2.369
4610	5.190	5.402	5.505	5.527	6.035	6.080
5000	7.902	8.140	8.257	8.027	8.770	8.760
5410	12.505	12.700	12.790	12.370	13.190	13.260

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel			Concrete	Deflection
	Top	Center	Bottom	Center	
1000	0.025	0.012	0.023	-0.020	
1990	0.040	0.040	0.040	0.006	
2980	0.105	0.093	0.156	0.060	
3275	0.166	0.154	0.190	0.096	
3480	0.212	0.175	0.253	0.105	None
3720	0.255	0.233	0.357	0.151	Apparent
3975	0.385	0.406	0.596	0.390	
4610	1.182	1.257	1.262	1.020	
5000	1.777	1.771	1.806	1.559	
5410	2.986	3.086	3.229	2.705	

This column exceeded the capacity of the machine.

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COLUMN NO. 8990-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
1000	0.238	0.265	0.264	0.258	0.305	0.317
1500	0.415	0.494	0.463	0.482	0.545	0.552
1725	0.521	0.619	0.604	0.619	0.723	0.737
1990	0.624	0.735	0.711	0.749	0.903	0.933
2240	0.731	0.863	0.860	0.885	1.150	1.206
2500	0.922	1.095	1.069	1.121	1.836	1.882
2820	1.348	1.498	1.772	1.653	3.161	3.468
3240	3.001	3.202	3.442	3.352	5.000	5.319
3410	13.220	13.190	15.680	13.650	20.170	21.070

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection N.	Deflection W.
1000	0.021	-0.001	-0.016	0.064		
1500	0.077	-0.017	0.023	0.065		
1725	0.058	0.005	0.053	0.025		
1990	0.065	0.051	0.099	0.086		
2240	0.115	0.062	0.221	0.148	0	0
2500	0.121	0.118	0.440	0.177	0.03"	0.03"
2820	0.190	0.355	1.111	0.382	0.09"	0.10"
3240	0.741	1.296	2.819	1.193	0.31"	0.39"
3410	2.049	2.564	4.087	2.881	Max. Load.	

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COLUMN NO. 8990-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
995	0.327	0.378	0.322	0.368	0.317	0.364
1735	0.635	0.731	0.566	0.667	0.612	0.767
1990	0.804	0.912	0.694	0.816	0.755	0.904
2240	0.978	1.066	0.833	0.965	0.911	1.102
2480	1.331	1.377	0.932	1.095	1.230	1.429
2690	1.869	1.884	1.278	1.484	2.267	2.478
2790	2.654	2.418	1.851	2.032	3.288	3.472
3120	4.157	3.910	3.170	3.460	4.917	4.650
3500	10.830	11.160	13.000	14.020	13.640	11.830

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection N.	Deflection W.
995	-0.004	0.005	-0.113	-0.097		
1735	0.066	0.057	-0.028	-0.033		
1990	0.046	0.060	0.015	-0.042		
2240	0.034	0.079	0.027	-0.043		
2480	0.201	0.123	0.196	0.019		
2690	0.428	0.260	0.543	0.097		
2790	0.756	0.612	1.045	0.292		
3120	1.271	1.126	1.526	0.849	0.22"	0.18"
3500	3.390	2.675	2.600	2.332	1.19"	0.39"

COLUMN NO. 8990-3

Average Unit Defomations onLongitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
1000	0.293	0.305	0.268	0.275	0.269	0.269
1750	0.571	0.592	0.523	0.543	0.585	0.594
2000	0.730	0.732	0.649	0.662	0.724	0.747
2250	0.895	0.914	0.801	0.821	0.902	0.947
2500	1.072	1.130	1.010	0.988	1.135	1.197
2745	1.404	1.499	1.119	1.112	1.586	1.585
3000	2.418	2.448	1.650	1.619	2.804	2.856
3250	3.774	4.167	2.839	2.866	4.291	4,533
3630	9.992	8.148	9.170	9.375	11.062	11.947
34.7	8.352	9.041	7.690	8.690	9.370	10.161

Average Unit Defomations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection N.	Deflection W.
1000	0.005	0.025	-0.011	0.028		
1750	0.131	0.102	0.070	0.123		
2000	0.121	0.077	0.087	0.093		
2250	0.100	0.135	0.140	0.132		
2500	0.140	0.156	0.213	0.162		
2745	0.254	0.238	0.385	0.228		
3000	0.587	0.522	0.915	0.436		
3250	1.136	1.058	1.735	0.811	0.03"	0.10"
3630	2.356	3.209	3.764	2.353	0.18"	1.01"
34.7	1.447	2.691	2.844	1.801		

COLUMN NO. 8992-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
980	0.207	0.161	0.219	0.182	0.162	0.195
1930	0.427	0.444	0.449	0.420	0.438	0.454
2420	0.591	0.593	0.592	0.590	0.606	0.649
2890	0.767	0.761	0.780	0.780	0.818	0.863
3375	1.001	0.958	0.979	0.975	1.064	1.116
3860	1.243	1.261	1.220	1.220	1.382	1.371
4255	1.630	1.560	1.662	1.756	2.810	2.847
4430	2.127	1.991	2.467	2.548	3.930	3.935
4730	3.816	3.860	4.530	4.751	4.570	4.797
4910	8.030	8.340	11.920	12.310	13.880	13.370

Average Unit Defomations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel			Concrete	Deflection
	Top	Center	Bottom	Center	
980	0.046	0.008	0.012	0.088	
1930	0.056	0.024	0.092	0.132	
2420	0.075	0.066	0.136	0.175	
2890	0.137	0.097	0.186	0.230	
3375	0.202	0.124	0.260	0.268	
3860	0.263	0.181	0.343	0.335	
4255	0.367	0.357	0.910	0.497	
4430	0.633	0.696	1.338	0.837	
4730	1.352	1.607	2.225	1.635	
4910	3.296	3.164	3.762	3.063	

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COLUMN NO. 8992-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Concrete	Steel	Concrete	Steel	Concrete	Steel
1030	0.216	0.264	0.222	0.254	0.262	0.225
2000	0.519	0.626	0.505	0.555	0.515	0.556
2500	0.613	0.753	0.644	0.700	0.737	0.780
3000	0.888	1.017	0.935	0.972	1.009	1.063
3500	1.109	1.239	1.134	1.257	1.257	1.356
3920	1.436	1.575	1.326	1.379	2.799	2.833
4180	2.732	2.967	2.590	2.432	4.842	4.995
4410	4.990	4.942	4.905	4.840	7.550	7.715

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection N.	Deflection W.
1030	0.121	0.028	-0.001	0.077		
2000	0.180	0.071	0.037	0.122		
2500	0.207	0.098	0.098	0.131		
3000	0.251	0.166	0.160	0.210		
3500	0.261	0.214	0.243	0.280		
3920	0.353	0.264	0.890	0.317		
4180	0.767	0.762	1.630	0.753	0.16"	0.01"
4410	1.496	1.573	2.601	1.600	0.49"	0.11"

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COLUMN NO. 8992-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.203	0.206	0.204	0.210	0.206	0.212
2000	0.515	0.540	0.518	0.545	0.528	0.536
2500	0.662	0.694	0.698	0.731	0.774	0.761
3000	0.836	0.897	0.887	0.933	0.936	0.987
3510	1.069	1.137	1.119	1.200	1.247	1.313
3730	1.216	1.263	1.360	1.449	1.660	1.706
4000	2.160	1.911	2.986	3.135	3.598	3.638
4250	5.640	5.202	7.447	7.902	7.355	7.652

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.		Steel		Concrete	Deflection	
	Top	Center	Bottom	Center	N.	E.
1000	0.022	0.002	0.011	-0.004		
2000	0.019	0.012	0.047	0.002		
2500	0.028	0.041	0.060	0.052		
3000	0.072	0.071	0.111	0.078	0	0
3510	0.102	0.150	0.196	0.145	0.06	0.06"
3730	0.163	0.186	0.312	0.188	0.09"	0.06"
4000	0.530	0.831	1.155	0.756	0.15"	0.08"
4250	1.827	2.394	2.892	2.366	0.67"	-.29"
4310	Maximum Load.				1.66"	-.56"

COLUMN NO. 8993-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.223	0.212	0.207	0.211	0.240	0.237
2000	0.533	0.542	0.530	0.538	0.606	0.614
2500	0.716	0.689	0.727	0.739	0.839	0.863
3500	1.152	1.138	1.167	1.207	1.390	1.436
3940	1.566	1.454	1.576	1.590	3.084	3.048
4290	3.326	3.198	3.482	3.954	5.862	5.758
4860	11.425	11.319	7.390	8.927	0.450	1.170

Average Unit Deformations onLateral Gage Lines.

Load lbs. per sq. in.	Steel			Concrete	Deflection	
	Top	Center	Bottom	Center	S.	E.
1000	-0.125	-0.040	-0.062	-0.028		
2000	-0.113	0.007	-0.013	0.011		
2500	-0.016	0.000	0.005	0.018		
3500	0.055	0.134	0.106	0.112	0	0
3940	0.056	0.199	0.403	0.115	0	0.11"
4290	0.418	0.619	0.786	0.582	0.11"	0.36"
4860	1.050	0.780	———	2.322	Max. Load.	

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COLUMN NO. 8993-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Center Concrete	Center Steel	Bottom Concrete	Bottom Steel
1000	0.280	0.263	0.207	0.225	0.209	0.225
2000	0.624	0.619	0.461	0.533	0.521	0.542
2500	0.815	0.838	0.615	0.655	0.736	0.775
3000	1.058	1.080	0.763	0.863	0.958	1.033
3500	1.659	1.751	0.893	1.007	1.239	1.331
3740	2.569	2.847	0.982	1.117	1.854	1.850
4180	6.032	6.200	1.557	1.590	4.467	4.015
5030	18.523	19.591	12.380	13.070	15.135	15.395

Average Unit Deformations onLateral Gage Lines.

Load lbs. per sq. in.	Steel Top	Steel Center	Steel Bottom	Concrete Center	Deflection S.	Deflection E.
1000	-0.007	0.002	0.018	-0.008		
2000	0.001	-0.004	0.027	0.025		
2500	0.022	0.018	0.043	0.026		
3000	0.085	0.065	0.113	0.075		
3500	0.225	0.104	D.168	0.118		
3740	0.485	0.128	0.353	0.151		
4180	0.987	0.415	0.953	0.397	0	0
5030	2.592	1.840	1.837	1.607	1.18"	1.63"

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COLUMN NO. 8993-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Center		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel
1015	0.240	0.237	0.223	0.233	0.226	0.218
2000	0.544	0.546	0.462	0.524	0.511	0.545
3015	0.937	0.980	0.814	0.941	0.935	1.007
3260	1.053	1.106	0.909	1.052	1.056	1.142
3500	1.190	1.236	1.019	1.172	1.187	1.282
4000	1.802	1.814	1.285	1.503	2.101	2.162
4390	3.540	3.614	3.030	3.636	4.509	5.313
4560	4.667	4.835	3.512	3.915	5.802	6.130
5050	13.172	13.712	14.232	16.317	15.852	16.345

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.		Steel		Concrete	Deflection	
	Top	Center	Bottom	Center	S.	W.
1015	-0.007	-0.003	0.011	0.023		
2000	-0.022	0.014	0.012	0.022		
3015	0.062	0.077	0.095	0.077		
3260	0.085	0.071	0.121	0.073		
3500	0.156	0.117	0.150	0.121		
4000	0.322	0.195	0.430	0.201	0	0
4390	0.805	0.554	1.005	0.575	0.05"	0.12"
4560	1.056	0.771	1.236	0.821	0.09"	0.27"
5050	2.970	1.960	3.130	3.305	0.89"	2.30"

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COLUMN NO. 8994-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
860	0.196	0.244	0.287	0.244	0.281	0.303	0.255	0.253	0.246	0.255
1245	0.364	0.394	0.403	0.419	0.440	0.478	0.424	0.411	0.416	0.417
1490	0.474	0.519	0.551	0.586	0.599	0.631	0.501	0.498	0.565	0.589
1740	0.549	0.592	0.637	0.624	0.729	0.777	0.597	0.599	0.704	0.719
1990	0.682	0.719	0.792	0.863	0.905	0.968	0.739	0.719	0.895	0.913
2240	0.828	0.873	0.985	1.058	1.236	1.304	0.908	0.858	1.136	1.145
2495	1.052	1.085	1.463	1.511	2.024	2.127	1.001	1.032	1.814	1.715
2780	1.562	1.721	2.336	2.367	3.410	3.541	1.390	1.367	3.292	3.236
3080	2.729	2.737	3.923	3.993	3.233	2.809	2.439	2.335	4.279	4.299

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection	
	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	N.	W.
860	0.017	0.005	0.028	-0.024	-0.016	0.005	-0.017		
1245	0.040	-0.005	0.020	-0.021	-0.050	-0.015	-0.035		
1490	-0.017	-0.008	0.048	-0.004	-0.025	0.028	0.033		
1740	0.063	0.027	0.091	0.016	-0.050	0.030	0.043		
1990	0.062	0.025	0.103	0.054	-0.037	0.022	0.083		
2240	0.091	0.087	0.133	0.175	-0.026	0.071	0.138		
2495	0.115	0.155	0.242	0.475	-0.004	0.085	0.417	0	0
2780	0.165	0.441	0.560	1.086	0.053	0.170	1.028	0.10"	0.02"
3080	0.463	0.920	1.116	1.816	0.575	0.598	1.843	0.65"	0.38"

COLUMN NO. 8994-2

Average Unit Deformations on Longitudinal Gage Lines.

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Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
800	0.158	0.197	0.193	0.204	0.263	0.288	0.206	0.285	0.231	0.254
1510	6.578	0.607	0.563	0.571	0.690	0.718	0.516	0.621	0.726	0.712
1760	0.777	0.785	0.680	0.724	0.922	0.805	0.680	0.784	0.938	0.913
2100	1.130	1.069	0.808	0.907	1.307	1.129	0.833	0.954	1.428	1.346
2270	1.911	1.792	1.174	1.261	1.819	1.792	1.163	1.252	2.544	2.280
2510	3.702	3.707	1.766	1.726	3.625	3.714	1.985	2.007	4.518	4.255

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point		Center Steel	Quarter Point		Bottom Steel	Deflection	
		Concrete	Steel		Concrete	Steel		S.	E.
800	-0.026	-0.027	-0.038	-0.045	0.020	-0.025	-0.010		
1510	-0.002	-0.011	0.001	0.015	0.033	0.000	-0.003		
1760	0.083	0.011	-0.027	0.102	0.011	-0.010	-0.020	0	0
2100	0.192	0.011	0.037	0.229	0.125	0.072	0.122	0.03"	0.04"
2270	0.505	0.101	0.128	0.640	0.191	0.280	0.456	0.08"	0.22"
2510	1.085	0.276	0.206	1.191	0.546	0.417	0.971	0.45"	0.80"

COLUMN NO. 8994-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		BOttom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.345	0.350	0.387	0.396	0.305	0.301	0.332	0.345	0.363	0.348
1500	0.592	0.601	0.651	0.664	0.503	0.479	0.541	0.585	0.657	0.653
1745	0.729	0.767	0.838	0.856	0.608	0.593	0.635	0.711	0.807	0.809
2000	0.892	0.920	1.028	1.125	0.727	0.725	0.759	0.874	1.046	1.022
2245	1.213	1.141	1.570	1.593	0.870	0.873	0.943	1.084	1.481	1.359
2500	1.934	1.429	2.564	2.418	1.067	1.059	1.300	1.496	2.681	2.522
2910	7.040	5.70	6.730	6.440	5.570	4.415	2.495	2.577	7.640	7.460

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point		Center Steel	Quarter Point		Bottom Steel	Deflection	
		Concrete	Steel		Concrete	Steel		N.	W.
1000	0.002	0.002	0.017	0.004	0.020	-0.007	0.027		
1500	0.010	0.043	0.056	0.044	0.023	0.017	0.068		
1745	0.051	0.037	0.062	0.037	0.002	-0.007	-0.004	0	0
2000	0.068	0.098	0.143	0.068	0.028	0.017	0.087	0.04"	0.02"
2245	0.086	0.146	0.211	0.080	0.077	0.058	0.263	0.06"	0.02"
2500	0.210	0.378	0.560	0.105	0.110	0.132	0.770	0.10"	-.05"
2910	1.745	1.442	1.737	1.189	0.683	0.776	2.011	2.00"	-.81"

COLUMN NO. 8995-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Concrete	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Concrete	Bottom Steel
1000	0.267	0.263	0.284	0.285	0.299	0.289	0.260	0.266	0.277	0.281
2000	0.589	0.553	0.600	0.591	0.603	0.567	0.551	0.580	0.631	0.658
2500	0.780	0.785	0.827	0.815	0.800	0.786	0.778	0.809	0.881	0.879
3000	1.001	1.036	1.102	1.084	1.021	0.998	0.993	1.035	1.165	1.158
3500	1.282	1.277	1.493	1.467	1.288	1.250	1.318	1.468	1.613	1.706
3800	2.072	1.904	2.447	2.408	2.535	2.275	1.992	2.144	3.226	3.643
3850	3.176	2.969	2.933	2.999	4.514	3.418	2.495	2.713	5.770	5.368

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Steel	Deflection S.	Deflection W.
1000	-0.073	-0.050	-0.018	-0.012	-0.053	-0.057	-0.036		
2000	-0.006	-0.055	0.038	-0.010	-0.040	-0.018	0.040		
2500	-0.048	-0.035	0.046	0.056	-0.052	0.023	0.065		
3000	-0.127	-0.040	0.063	0.062	0.034	0.116	0.107	0	0.05"
3500	0.043	0.113	0.252	0.132	0.083	0.148	0.268	0.02"	0.11"
3800	0.345	0.401	0.745	0.525	0.386	0.538	0.991	0.09"	0.39"
3850	0.756	0.548	0.760	1.490	0.605	0.763	1.628	0.46"	1.54"

COLUMN NO. 8995-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.225	0.287	0.243	0.274	0.252	0.267	0.300	0.307	0.303	0.326
2000	0.543	0.617	0.544	0.618	0.630	0.685	0.622	0.665	0.798	0.769
2500	0.788	0.879	0.772	0.855	0.863	0.890	0.861	0.890	1.089	1.063
3000	1.029	1.171	0.996	1.116	1.185	1.211	1.110	1.173	1.504	1.425
3250	1.089	1.253	1.125	1.235	1.625	1.532	1.256	1.297	2.731	2.308
3500	2.022	2.023	1.532	1.550	3.824	3.946	1.969	1.807	6.230	5.882
3540	3.077	3.080	1.865	1.670	5.677	5.860	2.157	2.182	10.180	7.410

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection	
	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	N.	W.
1000	0.038	0.031	0.042	0.013	0.017	0.027	0.009		
2000	0.036	0.046	0.105	0.037	0.095	0.106	0.083		
2500	0.063	0.086	0.135	0.080	0.124	0.195	0.167		
3000	0.050	0.070	0.138	0.144	0.131	0.199	0.181	0	0
3250	0.098	0.110	0.170	0.287	0.190	0.225	0.556	0.10"	0
3500	0.288	0.186	0.275	1.135	0.542	0.740	1.371	0.65"	0.16"
3540	0.681	0.305	0.336	1.615	0.680	0.739	1.692	1.19"	0.37"

COLUMN NO. 8995-3

Average Unit Deformations on :ongitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.253	0.219	0.240	0.247	0.204	0.336	0.211	0.234	0.212	0.208
2000	0.574	0.484	0.597	0.617	0.521	0.528	0.521	0.546	0.570	0.554
2500	0.830	0.709	0.851	0.880	0.713	0.746	0.726	0.769	0.813	0.783
2745	1.037	0.926	1.081	1.088	0.895	0.943	0.906	0.965	0.999	0.988
3170	1.257	1.202	1.712	1.544	1.042	1.099	1.057	1.128	1.274	1.123
3420	2.080	1.828	3.022	2.739	1.528	1.332	1.195	1.261	1.964	1.644
3500	4.212	4.012	4.755	4.730	3.710	3.782	2.290	1.827	4.242	4.056

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection	
	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	S.	W.
1000	0.045	0.028	0.018	-0.021	-0.002	0.042	0.016		
2000	0.045	0.078	0.062	0.000	0.032	0.077	0.041		
2500	0.060	0.188	0.165	0.021	0.072	0.113	0.078	0	0
2745	0.098	0.272	0.267	0.097	0.111	0.203	0.128	0	0.05"
3170	0.145	0.503	0.502	0.125	0.185	0.266	0.223	0.02"	0.11"
3420	0.336	1.028	0.922	0.350	0.246	0.341	0.516	0.09"	0.39"
3500	1.097	1.685	1.451	1.516	0.457	0.650	1.406	0.46"	1.54"

COLUMN NO. 8996-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Quarter Point Concrete	Quarter Point Steel	Cneter Concrete	Cneter Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Concrete	Bottom Steel
1000	0.247	0.298	0.227	0.271	0.202	0.165	0.197	0.232	0.205	0.192
2000	0.582	0.635	0.529	0.575	0.514	0.463	0.485	0.538	0.497	0.489
2500	0.808	0.902	0.792	0.819	0.666	0.658	0.603	0.676	0.667	0.713
3000	1.067	1.154	1.018	1.080	0.883	0.881	0.797	0.910	0.859	0.899
3500	1.557	1.602	1.275	1.346	1.244	1.119	1.048	1.131	1.102	1.176
4000	4.035	4.160	3.057	2.992	1.799	1.871	1.334	1.397	1.566	1.570
4250	4.632	4.805	2.787	2.860	4.694	4.196	2.921	2.348	2.854	3.240

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Steel	Deflection. S.	Deflection. W.
1000	0.029	-0.030	-0.035	-0.001	-0.001	0.012	0.012		
2000	0.031	0.026	0.031	-0.001	0.048	0.060	0.027		
2500	0.047	0.031	-0.002	0.024	0.022	0.046	-0.029		
3000	0.140	0.062	0.102	0.044	0.115	0.101	0.039		
3500	0.261	0.147	0.182	0.128	0.182	0.171	0.072	0	0
4000	0.654	0.645	0.722	0.301	0.207	0.158	0.178	0.20"	0.07"
4250	1.563	1.213	1.703	1.428	0.477	0.450	0.382	1.60"	1.02"

COLUMN NO. 8996-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
1000	0.265	0.312	0.304	0.315	0.229	0.276	0.254	0.271	0.303	0.314
2000	0.530	0.602	0.599	0.604	0.473	0.554	0.511	0.566	0.617	0.628
2500	0.673	0.775	0.792	0.812	0.652	0.758	0.716	0.798	0.779	0.914
3000	0.868	0.973	1.000	1.055	0.829	0.973	0.911	1.021	1.107	1.115
3500	1.086	1.212	1.268	1.339	1.024	1.208	1.147	1.291	1.501	1.466
3750	1.253	1.366	1.654	1.632	1.160	1.338	1.398	1.577	2.191	2.063
4000	1.692	1.740	2.499	2.182	1.735	1.840	2.201	2.425	3.611	3.262
4270	4.785	4.792	4.340	3.735	5.070	5.740	4.027	4.080	7.765	7.607

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection.	
	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	S.	E.
1000	0.006	-0.005	0.026	-0.018	-0.009	-0.032	0.032		
2000	0.021	0.021	0.060	0.027	0.052	0.002	0.081		
2500	0.066	0.043	0.083	0.042	0.093	0.042	0.108		
3000	0.078	0.073	0.102	0.089	0.145	0.112	0.165		
3500	0.115	0.080	0.120	0.109	0.203	0.125	0.276		
3750	0.126	0.152	0.125	0.146	0.238	0.185	0.382	0	0
4000	0.186	0.310	0.305	0.370	0.520	0.456	0.837	0.13"	0.07"
4270	1.031	0.780	0.717	1.347	1.035	0.878	1.773	2.04"	0.19"

COLUMN NO. 8996-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Concrete	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Concrete	Bottom Steel
1000	0.248	0.246	0.232	0.267	0.256	0.256	0,266	0.266	0.278	0.275
2000	0.579	0.588	0.578	0.653	0.554	0.579	0.575	0.592	0.605	0.611
2750	0.893	0.940	0.950	1.046	0.916	0.940	0.952	0.996	0.991	1.030
3000	1.047	1.078	1.095	1.221	1.025	1.075	1.060	1.104	1.185	1.203
3250	1.294	1.311	1.484	1.757	1.211	1.222	1.237	1.268	1.727	1.774
3500	1.623	1.612	2.080	2.298	1.637	1.570	1.571	1.527	2.450	2.119
3680	3.008	2.853	3.119	3.311	3.044	2.868	2.548	2.484	4.201	4.237
3760	6.527	5.127	3.995	4.242	6.144	5.952	3.412	3.335	6.932	7.257

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Steel	Deflection. N.	Deflection. E.
1000	0.027	0.019	0.045	-0.014	0.011	0.002	0.020		
2000	0.045	0.062	0.067	0.026	0.070	0.083	0.112		
2750	0.063	0.129	0.142	0.070	0.120	0.119	0.147		
3000	0.077	0.161	0.176	0.093	0.144	0.145	0.225	0	0
3250	0.106	0.220	0.241	0.121	0.174	0.172	0.334	0.02"	0.12"
3500	0.198	0.392	0.408	0.232	0.300	0.243	0.537	0.03"	0.34"
3680	0.518	0.642	0.607	0.656	0.692	0.578	0.931	-0.10"	1.06"
3760	1.121	0.925	0.866	1.351	0.937	0.792	1.598	0	2.85"

COLUMN NO. 8997-1

Average Unit Deformations on Longitudinal Gage Lines.

Load	Top		Quarter Point		Center		Quarter Point		Bottom	
lbs. per sq. in.	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
750	0.266	0.252	0.261	0.307	0.234	0.254	0.235	0.227	0.233	0.220
1220	0.519	0.510	0.520	0.542	0.393	0.377	0.371	0.408	0.448	0.439
1750	0.864	0.870	0.769	0.858	0.595	0.577	0.638	0.634	0.743	0.720
1995	1.340	1.213	1.070	1.199	0.797	0.804	0.897	0.887	0.931	0.935
2250	1.760	2.120	1.461	1.711	0.918	0.959	0.981	0.943	1.203	1.168
2500	4.133	4.019	2.467	3.153	1.079	1.056	1.155	1.177	2.212	2.136
2570	6.343	6.517	3.244	3.985	1.414	1.369	1.346	1.387	3.248	2.990

Average Unit Deformations on Lateral Gage Lines.

Load	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection.	
lbs. per sq. in.	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	S.	W.
750	-0.035	-0.086	-0.030	-0.080	0.000	-0.006	-0.074		
1220	-0.047	-0.035	-0.016	-0.122	-0.013	-0.012	-0.074		
1750	-0.030	0.042	0.056	-0.118	0.012	0.010	-0.050		
1995	-0.045	0.017	-0.028	-0.147	-0.005	-0.082	-0.030	0	0
2250	0.272	0.274	0.166	-0.117	0.030	-0.012	0.135	0.03"	0.06"
2500	0.884	0.803	0.697	-0.107	0.104	0.052	0.480	0.17"	0.60"
2570	1.471	1.046	0.895	-0.042	0.157	0.164	0.831	0.34"	1.45"

COLUMN NO. 8997-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Concrete	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Concrete	Bottom Steel
750	0.191	0.236	0.2530	0.245	0.266	0.264	0.264	0.292	0.200	0.214
1080	0.426	0.458	0.515	0.513	0.494	0.490	0.532	0.597	0.426	0.487
1310	0.611	0.658	0.719	0.685	0.643	0.642	0.745	0.831	0.578	0.664
1520	0.737	0.791	0.859	0.854	0.791	0.782	0.984	1.048	0.735	0.834
1740	1.027	1.002	1.090	1.075	0.956	0.967	1.434	1.358	0.932	1.041
1950	1.361	1.303	1.510	1.500	1.261	1.262	2.223	2.156	1.252	1.496
2075	1.955	1.627	1.993	1.997	1.759	1.762	3.030	3.097	1.857	2.134
2140	3.262	2.660	2.661	2.589	3.096	2.806	3.671	3.785	2.979	3.219

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Steel	Deflection. N.	Deflection. W.
750	-0.042	-0.005	-0.026	0.010	0.029	0.029	-0.010		
1080	0.009	0.065	0.043	0.049	0.076	0.102	0.009		
1310	-0.007	0.105	0.043	0.077	0.119	0.126	0.069	0	0
1520	0.092	0.172	0.084	0.107	0.139	0.135	0.122	0	0.05"
1740	0.090	0.284	0.174	0.156	0.315	0.314	0.200	0.02"	0.07"
1950	0.157	0.472	0.310	0.267	0.571	0.613	0.344	0.07"	0.12"
2075	0.325	0.746	0.495	0.564	0.726	0.851	0.517	0.22"	0.40"
2140	0.720	0.996	0.734	0.925	0.875	0.991	0.878	0.60"	1.20"

COLUMN NO. 8997-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
750	0.251	0.262	0.298	0.313	0.232	0.267	0.225	0.264	0.239	0.256
1250	0.453	0.476	0.528	0.551	0.456	0.509	0.455	0.528	0.513	0.546
1500	0.565	0.660	0.657	0.686	0.562	0.635	0.583	0.677	0.674	0.730
1760	0.705	0.725	0.831	0.874	0.709	0.806	0.724	0.825	0.860	0.920
2000	0.867	0.882	1.057	1.067	0.897	1.020	0.905	1.034	1.246	1.254
2250	1.317	1.179	1.899	1.369	1.436	1.631	1.371	1.521	2.649	2.539
2340	3.139	2.722	2.666	2.237	2.996	3.703	1.987	2.033	5.003	4.923

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection.	
	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	N.	W.
750	-0.046	-0.013	0.007	-0.011	-0.045	-0.017	0.000		
1250	-0.025	0.061	0.071	0.006	0.009	0.022	0.015		
1500	-0.015	0.113	0.117	0.037	0.006	0.061	0.062		
1760	-0.010	0.164	0.180	0.044	0.034	0.078	0.098	0	0
2000	0.011	0.247	0.278	0.113	0.100	0.150	0.215	0.02"	0.02"
2250	0.105	0.580	0.602	0.458	0.234	0.315	0.834	0.09"	0.35"
2340	0.705	0.887	0.842	1.337	0.411	0.532	1.572	0.70"	2.11"

COLUMN NO. 8998-1

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
1020	0.347	0.303	0.259	0.234	0.229	0.244	0.243	0.236	0.207	0.212
2000	0.923	0.731	0.586	0.614	0.587	0.606	0.570	0.533	0.530	0.597
2280	1.068	0.844	0.685	0.668	0.724	0.747	0.690	0.669	0.684	0.673
2700	1.404	1.087	0.876	0.871	0.893	0.926	0.865	0.822	0.840	0.837
3000	1.895	1.437	0.999	1.001	1.081	1.111	0.841	0.969	0.996	0.998
3000	2.020	1.494	1.098	1.139	1.162	1.194	0.958	0.965	1.022	0.975
3510	4.330	3.930	1.340	1.321	1.452	1.620	1.245	1.202	1.415	1.242
3810	5.023	5.171	2.342	2.422	2.542	3.123	1.484	1.513	4.938	5.420

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection.	
	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	S.	E.
1020	0.010	0.030	0.016	0.005	0.047	-0.022	0.041		
2000	0.061	0.026	0.006	0.058	0.030	-0.002	0.035	0	0
2280	0.135	0.068	0.000	0.078	-0.049	0.022	0.027	0.03"	0
2700	0.209	0.033	-0.015	0.090	0.047	0.014	-0.035	0.05"	0
3000	0.405	0.052	0.017	0.162	0.089	0.027	0.055	0.05"	0
3000	0.522	0.094	0.062	0.187	0.325	0.257	0.166	0.07"	0
3510	1.100	0.039	-0.005	0.227	0.062	0.034	0.015	0.08"	0.02"
3810	2.962	0.439	0.498	1.467	0.209	0.160	0.359	1.93"	0.55"

COLUMN NO. 8998-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Concrete	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Concrete	Bottom Steel
1010	0.227	0.223	0.202	0.201	0.182	0.227	0.275	0.276	0.233	0.267
2000	0.499	0.570	0.511	0.584	0.502	0.576	0.628	0.656	0.571	0.649
2500	0.684	0.830	0.785	0.851	0.754	0.850	0.893	0.923	0.834	0.942
2750	0.809	0.959	0.882	0.992	0.860	0.969	1.016	1.070	0.964	1.092
3010	0.925	1.136	1.059	1.175	1.013	1.149	1.141	1.185	1.109	1.245
3250	1.059	1.261	1.139	1.335	1.114	1.266	1.289	1.338	1.258	1.404
3385	1.395	1.535	1.418	1.570	1.566	1.811	1.522	1.564	2.296	2.422

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Steel	Deflection. N.	Deflection. W.
1010	0.035	0.070	0.073	0.063	0.000	0.016	-0.009		
2000	0.007	0.035	0.067	0.049	0.025	0.015	0.061		
2500	0.016	0.080	0.117	0.108	0.056	0.078	0.136		
2750	0.052	0.122	0.158	0.108	0.092	0.126	0.210	0	0
3010	0.059	0.134	0.181	0.162	0.080	0.111	0.190	0.04"	0.04"
3250	0.034	0.092	0.158	0.182	0.135	0.143	0.264	0.02"	0.05"
3385	0.105	0.158	0.330	0.380	0.173	0.246	0.720	-0.10"	0.62"

COLUMN NO. 8998-3

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top		Quarter Point		Center		Quarter Point		Bottom	
	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel	Concrete	Steel
1010	0.261	0.260	0.270	0.265	0.249	0.259	0.280	0.267	0.234	0.247
2000	0.572	0.571	0.550	0.567	0.499	0.527	0.573	0.564	0.565	0.568
2500	0.824	0.806	0.753	0.783	0.692	0.741	0.795	0.793	0.782	0.792
2740	0.977	0.919	0.880	0.919	0.817	0.878	0.929	0.929	0.933	0.945
2980	1.142	1.077	1.014	1.066	0.916	1.008	1.051	1.068	1.083	1.100
3245	1.465	1.332	1.183	1.238	1.082	1.160	1.221	1.203	1.280	1.274
3430	2.053	1.847	1.345	1.398	1.258	1.350	1.330	1.252	1.839	1.647
3470	3.167	2.935	1.659	1.665	1.897	2.046	1.587	1.420	3.185	2.838

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top	Quarter Point		Center	Quarter Point		Bottom	Deflection.	
	Steel	Concrete	Steel	Steel	Concrete	Steel	Steel	S.	E.
1010	0.020	0.031	0.043	0.018	-0.010	0.024	0.007		
2000	0.061	0.070	0.062	0.062	0.039	0.096	0.030		
2500	0.166	0.106	0.128	0.082	0.061	0.135	0.052	0	0
2740	0.219	0.106	0.151	0.070	0.057	0.142	0.118	0.06"	0.05"
2980	0.255	0.130	0.176	0.097	0.129	0.186	0.134	0.06"	0.05"
3245	0.334	0.155	0.204	0.111	0.107	0.197	0.176	0.09"	0.07"
3430	0.597	0.211	0.275	0.168	0.143	0.232	0.372	0.27"	0.17"
3470	0.996	0.321	0.378	0.458	0.197	0.354	1.007	0.50"	0.83"

COLUMN NO. 8999-1

Average Unit Deformations on Longitudinal Gage Lines.

Load Load lbs. per sq. in.	Top Concrete	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Concrete	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Concrete	Bottom Steel
1010	0.278	0.252	0.216	0.193	0.218	0.217	0.247	0.253	0.243	0.272
2020	0.582	0.548	0.478	0.510	0.501	0.555	0.554	0.556	0.597	0.634
2420	0.811	0.763	0.662	0.714	0.685	0.768	0.729	0.725	0.767	0.816
2725	0.923	0.824	0.776	0.832	0.774	0.865	0.870	0.824	0.913	0.956
3030	1.049	0.942	0.863	0.952	0.893	0.981	0.960	0.955	1.059	1.111
3335	1.257	1.157	0.993	1.111	1.029	1.131	1.157	1.134	1.259	1.300
3630	1.524	1.413	1.145	1.285	1.197	1.322	1.355	1.343	1.575	1.624
3820	2.616	2.457	1.328	1.401	1.662	1.880	1.769	1.631	2.646	2.538

Average Unit Deformations on Lateral Gage Lines.

Load lbs.per sq..in.	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Steel	Deflection. N.	Deflection. E.
1010	-0.047	-0.007	0.002	0.015	-0.013	-0.011	-0.032		
2020	-0.015	0.066	0.055	0.026	-0.012	-0.029	-0.025		
2420	0.016	0.017	-0.007	0.056	0.036	-0.015	0.005		
2725	-0.026	0.040	0.028	0.048	0.050	0.020	0.026		
3030	0.066	0.045	0.012	0.080	0.177	0.073	0.023	0	0
3335	0.002	0.061	0.057	0.115	0.162	0.103	0.075	0.02"	0
3630	0.177	0.115	0.076	0.184	0.211	0.181	0.142	0.13"	0
3820	0.408	0.089	0.072	0.288	0.294	0.257	0.394	0.67"	0.10"

COLUMN NO. 8999-2

Average Unit Deformations on Longitudinal Gage Lines.

Load lbs. per sq. in.	Top Concrete	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Concrete	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Concrete	Bottom Steel
1010	0.239	0.251	0.235	0.245	0.231	0.260	0.220	0.234	0.174	0.223
2110	0.571	0.617	0.533	0.571	0.587	0.653	0.574	0.601	0.550	0.635
2760	0.803	0.856	0.763	0.848	0.875	0.966	0.874	0.910	0.859	0.977
3010	0.914	0.970	0.839	0.969	1.000	1.123	0.994	1.046	1.000	1.151
3260	1.122	1.173	1.009	1.152	1.214	1.361	1.135	1.201	1.156	1.357
3550	1.208	1.304	1.078	1.263	1.654	1.916	1.272	1.305	1.635	1.773
3650	1.762	1.866	1.304	1.439	2.668	3.103	1.503	1.506	2.660	3.404
3680	2.646	2.634	1.466	1.590	3.955	3.255	1.679	1.634	3.536	$3.\overset{6}{1}86$

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point Concrete	Quarter Point Steel	Center Steel	Quarter Point Concrete	Quarter Point Steel	Bottom Steel	Deflection. N.	Deflection. W.
1010	-0.042	-0.029	-0.017	-0.009	-0.022	-0.020	-0.026		
2110	-0.016	0.001	0.013	0.029	0.049	0.033	0.019		
2760	0.019	0.029	0.040	0.119	0.110	0.089	0.076		
3010	0.036	0.030	0.075	0.157	0.121	0.107	0.090		
3260	0.060	0.013	0.043	0.202	0.109	0.087	0.097	0	0
3550	0.070	0.052	0.103	0.416	0.135	0.149	0.242	0	0.10"
3650	0.220	0.052	0.115	0.703	0.176	0.180	0.531	0.05"	0.68"
3680	0.484	0.103	0.201	1.141	0.231	0.267	0.873	0.06"	1.44"

COLUMN NO. 8999-3

The readings on the longitudinal gage lines have been discarded as the instrument was out of adjustment.

Average Unit Deformations on Lateral Gage Lines.

Load lbs. per sq. in.	Top Steel	Quarter Point		Center Steel	Quarter Point		Bottom Steel	Deflection.	
		Concrete	Steel		Concrete	Steel		S.	W.
1025	-0.015	0.005	0.004	-0.010	-0.015	-0.007	-0.004		
2000	-0.021	0.009	0.009	0.037	0.075	0.035	0.019	0	0
3000	0.223	0.150	0.150	0.115	0.197	0.141	0.217	0.08"	0.20"
3240	0.579	0.340	0.356	0.289	0.247	0.227	0.547	0.38"	0.89"
3280		Maximum Load						0.70"	1.74"

TABLE 6.

Col. No.	Stress in Spiral-lbs. per sq. in. 10,000 (1) Load lb. per sq.in.	(2) Long. Def.	(3) μ	20,000 (4) Load	(5) Long. Def.	(6) μ	30,000 (7) Load	(8) Long. Def.	(9) μ	40,000 (10) Load	(11) Long. Def.	(12) μ	Highest Stress in Spiral (13)	Col. No.
8986-1	2170	2.05	.163	2450	2.33	.200	2640	4.55	.220	2830	6.00	.242	45000	8986-1
8986-2	2170	1.75	.190	2380	2.65	.251	2550	3.60	.278	2700	4.90	.296	44000	8986-2
8986-3	2430	1.45	.229	2670	2.30	.289	2830	3.01	.332	2980	3.90	.372	45400	8986-3
Ave.	2257	1.75	.194	2500	2.43	.280	2673	3.72	.277	2837	4.93	.303	44970	Ave.
8988-1	3450	1.33	.250	3930	2.23	.299	4150	3.05	.328	4350	4.13	.351	45600	8988-1
8988-2	3810	1.58	.211	4030	2.37	.281	4200	3.25	.308	----	----	----	35000	8988-2
8988-3	3330	1.68	.198	3540	2.55	.261	3700	3.80	.263	3850	5.10	.284	45500	8988-3
Ave.	3527	1.53	.219	3833	2.38	.280	4017	3.37	.299	4100	4.61	.312	45550	Ave.
8989-1	3300	1.30	.257	3800	2.53	.263	4150	4.18	.239	4700	7.90	.205	41500	8989-1
8989-2	4050	1.82	.183	4480	3.22	.207	4700	4.95	.202	5050	8.14	.196	41800	8989-2
8989-3	3800	1.53	.218	4150	3.03	.220	4450	4.80	.208	4900	7.60	.211	42400	8989-3
Ave.	3717	1.55	.219	4143	2.93	.230	4433	4.46	.216	4883	7.88	.204	41900	Ave.
8990-1	2640	1.64	.207	2900	2.44	.273	3050	3.09	.324	3200	3.75	.386	45500	8990-1
8990-2	2540	1.42	.235	2860	2.72	.245	3030	3.65	.274	3170	4.60	.316	45500	8990-2
8990-3	2780	1.49	.224	2980	2.21	.301	3150	3.10	.323	3300	4.26	.342	45000	8990-3
Ave.	2653	1.52	.222	2913	2.46	.273	3077	3.28	.307	3223	4.20	.348	45200	Ave.
8992-1	3970	1.49	.224	4300	2.22	.300	4520	3.21	.312	4750	5.53	.265	45200	8992-1
8992-2	3750	1.60	.208	4000	2.31	.288	4140	2.84	.352	4280	4.42	.328	43500	8992-2
8992-3	3800	1.66	.201	3960	2.44	.273	4030	3.11	.322	4100	4.08	.356	44000	8992-3
Ave.	3840	1.58	.211	4087	2.32	.287	4230	3.05	.329	4377	4.68	.316	44200	Ave.
8993-1	4080	2.78	.120	4470	4.98	.134	4860	7.15	.140	----	----	----	30000	8993-1
8993-2	3770	2.17	.153	4060	3.28	.203	4320	5.05	.198	4760	11.00	.145	41000	8993-2
8993-3	4000	1.86	.179	4310	3.60	.185	4520	4.87	.205	4750	6.90	.232	42300	8993-3
Ave.	3950	2.27	.151	4280	3.95	.174	4560	5.69	.181	4755	8.95	.188	41600	Ave.
8994-1	2570	1.69	.197	2800	2.37	.281	2990	2.93	.342	----	----	----	32500	8994-1
8994-2	2250	1.67	.199	2440	2.73	.244	----	----	----	----	----	----	23500	8994-2
8994-3	2490	1.74	.191	2610	2.59	.257	2740	3.54	.283	2850	4.88	.298	40000	8994-3
Ave.	2437	1.70	.196	2617	2.56	.261	2865	3.23	.312	2850	4.88	.298	32000	Ave.

TABLE 6(cont.)

Col. No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	Col. No.
8995-1	3760	1.90	.175	3800	2.55	.261	3850	2.48	.403	----	----	----	32500	8995-1
8995-2	3300	1.75	.190	3460	2.67	.250	3550	3.98	.251	----	----	----	30500	8995-2
8995-3	3250	1.38	.242	3420	2.01	.329	3460	2.90	.345	3500	3.66	.397	40200	8995-3
Ave.	3437	1.68	.202	3560	2.41	.280	3620	3.12	.333	3500	3.66	.397	34400	Ave.
8996-1	3930	2.17	.153	4090	2.75	.242	4210	3.11	.322	----	----	----	32300	8996-1
8996-2	3950	2.11	.158	4070	2.82	.236	4200	4.48	.223	----	----	----	32300	8996-2
8996-3	3470	1.76	.189	3680	2.80	.238	3730	3.80	.263	----	----	----	34500	8996-3
Ave.	3783	2.01	.166	3947	2.79	.239	4047	3.79	.269	----	----	----	33030	Ave.
8997-1	2460	2.11	.158	2570	3.24	.206	----	----	----	----	----	----	20500	8997-1
8997-2	1970	1.62	.206	2100	2.37	.281	----	----	----	----	----	----	25000	8997-2
8997-3	2170	1.42	.235	2310	2.21	.301	2350	3.14	.319	----	----	----	30000	8997-3
Ave.	2200	1.72	.199	2327	2.61	.263	2350	3.14	.319	----	----	----	25170	Ave.
8998-1	3530	1.99	.168	3650	2.53	.262	3770	3.42	.293	----	----	----	32500	8998-1
8998-2	3400	1.76	.189	----	----	----	----	----	----	----	----	----	12000	8998-2
8998-3	3440	1.45	.230	3470	2.18	.306	----	----	----	----	----	----	20000	8998-3
Ave.	3457	1.73	.196	3560	2.35	.284	3770	3.42	.293	----	----	----	26250	Ave.
8999-1	3830	1.93	.173	----	----	----	----	----	----	----	----	----	12000	8999-1
8999-2	3640	2.23	.149	----	----	----	----	----	----	----	----	----	17500	8999-2
8999-3	----	----	----	----	----	----	----	----	----	----	----	----	12000	8999-3
Ave.	3735	2.08	.161	----	----	----	----	----	----	----	----	----	13800	Ave.

TABLE 7.

Col. No.	E	E_c of Column	n	$\frac{E_c \text{ (Cylinders)}}{E_c \text{ (Column)}}$
8986-1	2,630,000	2,045,000	14.66	2.16
8986-2	2,500,000	1,900,000	15.78	1.62
8986-3	2,500,000	1,872,000	16.02	1.75
Ave.	2,565,000	1,939,000	15.47	1.84
8988-1	3,845,000	2,368,000	12.68	2.15
8988-2	3,705,000	2,183,000	13.73	1.35
8988-3	4,000,000	2,481,000	12.08	1.23
Ave.	3,850,000	2,344,000	12.83	1.58
8989-1	3,445,000	1,952,000	15.37	2.35
8989-2	4,000,000	2,529,000	11.87	1.30
8989-3	3,845,000	2,390,000	12.56	1.42
Ave.	3,763,000	2,290,000	13.27	1.69
8990-1	3,125,000	2,530,000	11.86	1.76
8990-2	2,700,000	2,095,000	14.32	1.59
8990-3	3,100,000	2,512,000	11.94	2.15
Ave.	2,975,000	2,379,000	12.71	1.83
8992-1	3,920,000	2,419,000	12.41	2.07
8992-2	4,162,000	2,518,000	11.93	2.09
8992-3	3,845,000	2,355,000	12.74	1.79
Ave.	3,976,000	2,431,000	12.36	1.98
8993-1	3,770,000	2,328,000	12.89	2.05
8993-2	3,750,000	2,271,000	13.20	1.63
8993-3	3,700,000	2,230,000	13.45	1.99
Ave.	3,740,000	2,276,000	13.18	1.89
8994-1	2,775,000	2,175,000	13.79	2.59
8994-2	2,500,000	1,905,000	15.74	1.91
8994-3	2,450,000	1,840,000	16.30	2.34
Ave.	2,575,000	1,973,000	15.28	2.42
8995-1	3,225,000	1,680,000	17.85	3.93
8995-2	3,125,000	1,580,000	18.98	3.62
8995-3	3,570,000	2,041,000	14.70	1.96
Ave.	3,307,000	1,767,000	17.18	3.17
8996-1	3,450,000	1,956,000	15.33	2.17
8996-2	3,450,000	1,927,000	15.56	2.59
8996-3	2,970,000	1,477,000	20.30	4.10
Ave.	3,290,000	1,786,000	17.06	2.95
8997-1	2,500,000	1,895,000	15.82	2.31
8997-2	2,000,000	1,369,000	21.80	2.03
8997-3	2,500,000	1,905,000	15.75	1.93
Ave.	2,330,000	1,723,000	17.79	2.09
8998-1	3,030,000	1,458,000	20.57	3.61
8998-2	3,445,000	1,872,000	16.02	3.09
8998-3	3,330,000	1,750,000	17.14	2.82
Ave.	3,268,000	1,693,000	17.91	3.17
8999-1	3,330,000	1,758,000	17.06	2.47
8999-2	3,445,000	1,990,000	15.07	3.59
8999-3	---------	---------	-----	----
Ave.	3,372,000	1,874,000	16.06	3.03

COL. No.
8986-
8986-
8986-
Av.
8988-
8988-
8988-
Av.
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8993

Av
12.15

TABLE VIII.

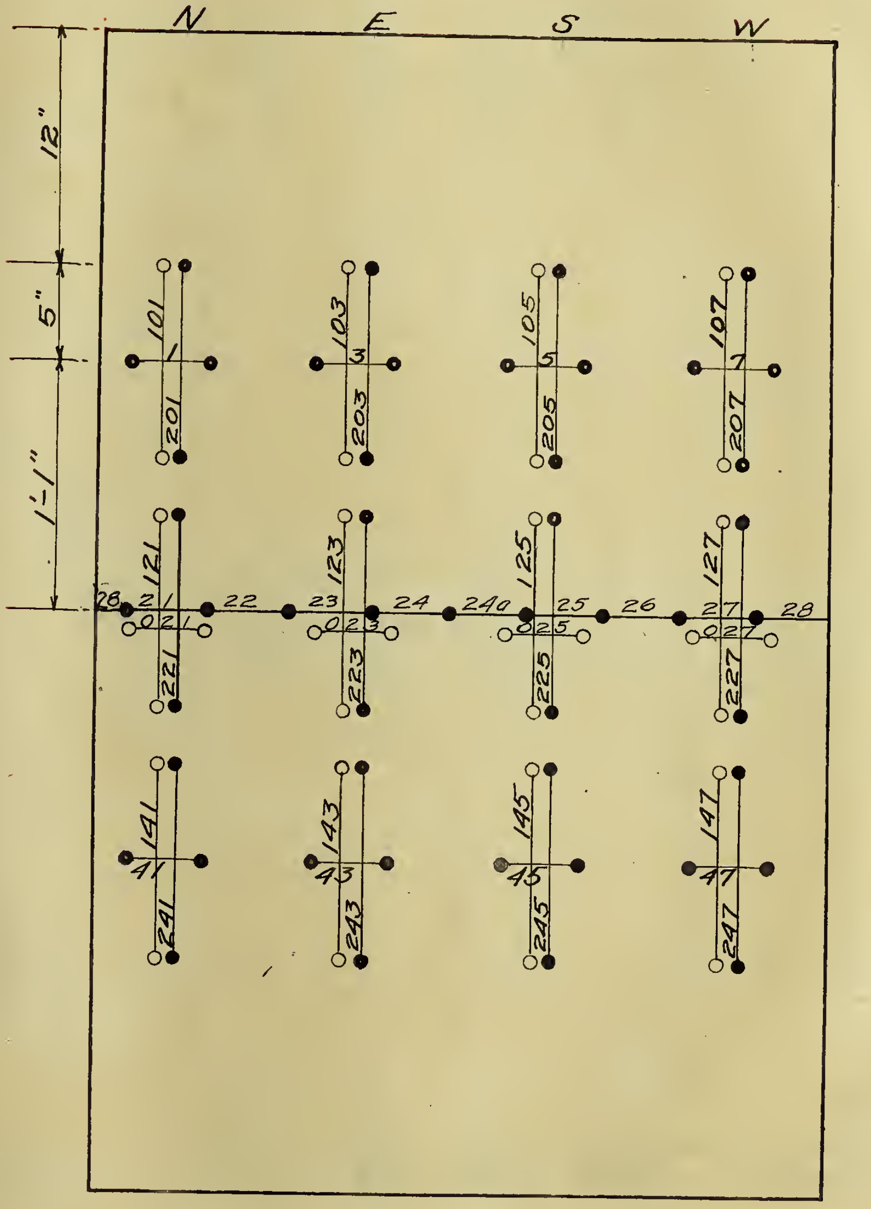
SUMMARY OF COLUMN DATA.

COL. No.	LENGTH	DIAM. OUTSIDE	DIAM O-O SPIRAL	AREA SQ. IN.	REINFORCEMENT. SPIRAL DIAM.	SPIRAL AREA	SPIRAL PERCENT	LONGITUDINAL DIAM.	LONGITUDINAL AREA	LONGITUDINAL PERCENT	DATE MADE	DATE TESTED	AGE DAYS	CYLINDERS AGE DAYS	CYLINDERS LOAD† lb. per sq. in.	CYLINDERS E_c	ULTIMATE LOAD lbs.	UNIT LOAD AT ULTIMATE	E_c OF COLUMN	UNIT LOAD AT CRUSHING	$\frac{B}{A}$	UNIT LOAD AT 0.001 IN. DEF. IN SP'L	POISSON'S RATIO AT SAME DEF.	COL. NO.
8986-1	5'-0"	12.41	12.22	117.2	.253	.0503	1.098	.625	.3067	2.091	12/18/15	2/12/16	56	58	1228	4,370,000†	445,000	3790	2,045,000	1928	1.57	2640	.220	8986-1
8986-2	"	12.45	12.18	116.3	.244	.0468	1.026	.629	.3107	2.135	1/3/16	3/4/16	61	65	1351	3,080,000	423,200	3630	1,900,000	1900	1.41	2550	.278	8986-2
8986-3	"	12.39	12.14	115.9	.257	.0519	1.136	.638	.3197	2.204	1/26/16	3/27/16	61	63	1622	3,280,000	453,300	3910	1,872,000	1738	1.07	2830	.332	8986-3
Av.				116.5			1.087			2.143					1400			3777	1,939,000	1855	1.35	2673	.277	Av.
8988-1	5'-0"	12.41	12.22	117.2	.249	.0487	1.063	1.000	.7854	5.355	12/15/15	2/8/16	55	55	1432	5,100,000	600,000	5110*	2,368,000	4000	2.79	4150	.328	8988-1
8988-2	"	12.46	12.13	115.5	.254	.0507	1.114	1.002	.7885	5.462	1/6/16	3/10/16	64	64	1945	2,942,000	650,000	5630*	2,183,000	4000	2.06	4200	.308	8988-2
8988-3	"	12.33	12.05	114.0	.246	.0475	1.051	1.000	.7854	5.504	1/29/16	3/30/16	61	60	1270	3,058,000†	572,000	5010	2,481,000	3850	3.06	3700	.263	8988-3
Av.				115.6			1.076			5.507					1549			5250	2,344,000	3950	2.64	4020	.299	Av.
8989-1	5'-0"	12.40	12.26	117.9	.375	.1104	2.332	1.000	.7854	5.325	12/4/15	1/31/16	58	59	1417	4,585,000	615,000	5215*	1,952,000	4005	2.84	4150	.239	8989-1
8989-2	"	12.49	12.27	118.1	.379	.1128	2.452	1.005	.7933	5.370	1/12/16	3/16/16	64	66	1787	3,280,000	655,000	5550*	2,529,000	4670	2.61	4700	.202	8989-2
8989-3	"	12.53	12.36	120.0	.381	.1140	2.459	1.003	.7901	5.271	2/2/16	4/3/16	61	59	1917	3,390,000	650,000	5410*	2,390,000	3715	1.94	4450	.208	8989-3
Av.				118.7			2.414			5.322					1707			5392	2,290,000	4130	2.46	4433	.216	Av.
8990-1	10'-0"	12.29	12.03	113.4	.251	.0495	1.100	.625	.3067	2.162	12/20/15	2/14/16	56	56	2146	4,450,000†	387,300	3410	2,530,000	2675	1.25	3050	.324	8990-1
8990-2	"	12.35	12.12	115.3	.249	.0487	1.072	.630	.3117	2.161	1/4/16	3/6/16	62	64	1790	3,335,000	404,700	3500	2,095,000	2690	1.50	3030	.274	8990-2
8990-3	"	12.32	12.12	115.3	.258	.0523	1.151	.628	.3097	2.147	1/26/16	3/28/16	62	58	1746	5,400,000	418,400	3630	2,512,000	2255	1.29	3150	.322	8990-3
Av.							1.108			2.157					1894			3513	2,379,000	2540	1.35	3077	.307	Av.
8992-1	10'-0"	12.29	11.94	112.0	.250	.0491	1.095	1.000	.7854	5.605	12/7/15	2/1/16	55	55	1850	5,000,000	550,700	4910	2,419,000	3855	2.07	4520	.312	8992-1
8992-2	"	12.38	12.09	114.8	.252	.0499	1.104	1.002	.7885	5.495	1/7/16	3/11/16	64	64	1807	5,260,000	530,400	4630	2,518,000	3510	1.94	4140	.352	8992-2
8992-3	"	12.30	12.05	114.0	.252	.0499	1.101	1.000	.7854	5.510	1/29/16	3/30/16	61	61	1686	4,210,000	491,200	4310	2,355,000	3790	2.25	4030	.322	8992-3
Av.							1.100			5.537					1781			4617	2,431,000	3718	2.09	4230	.329	Av.
8993-1	10'-0"	12.50	12.30	118.8	.378	.1122	2.431	1.000	.7854	5.285	12/14/15	2/7/16	55	56	1559	4,760,000	577,000	4860	2,328000	——	——	4860	.140	8993-1
8993-2	"	12.44	12.28	118.4	.375	.1104	2.400	1.003	.7901	5.341	1/12/16	3/16/16	64	66	1677	3,705,000	595,300	5030	2,271,000	3000	1.79	4320	.198	8993-2
8993-3	"	12.50	12.32	119.3	.376	.1110	2.401	1.003	.7901	5.300	2/2/16	4/4/16	62	59	1815	4,445,000	603,400	5050	2,230,000	3020	1.66	4520	.205	8993-3
Av.							2.408			5.309					1684			4980	2,276,000	3010	1.72	4570	.181	Av.
8994-1	15'-0"	12.30	12.02	113.4	.252	.0499	1.107	.625	.3067	2.162	12/21/15	2/19/16	60	66	2045	5,625,000†	357,700	3150	2,175,000	2240	1.10	2990	.342	8994-1
8994-2	"	12.37	12.05	114.0	.249	.0487	1.078	.621	.3029	2.123	1/5/16	3/7/16	62	63	1773	3,638,000	297,500	2610	1,905,000	2270	1.28	——	——	8994-2
8994-3	"	12.37	12.05	114.0	.253	.0503	1.113	.628	.3098	2.172	1/27/16	3/28/16	61	62	2054	4,300,000	332,700	2910	1,840,000	2245	1.09	2740	.283	8994-3
Av.							1.099			2.152					1957			2890	1,973,000	2252	1.16	2865	.312	Av.
8995-1	15'-0"	12.25	12.09	114.8	.249	.0487	1.074	1.000	.7854	5.470	12/16/15	2/10/16	56	60	1864	6,600,000	442,000	3850	1,680,000	3500	1.88	3850	.403	8995-1
8995-2	"	12.37	12.15	116.0	.253	.0503	1.103	1.002	.7885	5.440	1/10/16	3/13/16	63	63	1582	5,720,000	410,500	3540	1,580,000	3250	2.05	3550	.252	8995-2
8995-3	"	12.33	12.12	115.3	.252	.0499	1.099	1.002	.7885	5.470	1/31/16	3/31/16	60	61	1532	4,000,000	403,400	3500	2,041,000	3510	2.29	3460	.345	8995-3
Av.							1.092			5.460					1659			3630	1,767,000	3420	2.07	3620	.333	Av.
8996-1	15'-0"	12.69	12.24	117.8	.379	.1128	2.451	1.000	.7854	5.332	12/9/15	2/3/16	56	61	2594	4,255,000	500,200	4245	1,956,000	3500	1.35	4210	.322	8996-1
8996-2	"	12.43	12.24	117.8	.383	.1152	2.503	1.004	.7917	5.379	1/13/16	3/17/16	64	65	2005	5,000,000	502,400	4265	1,927,000	3735	1.86	4200	.223	8996-2
8996-3	"	12.62	12.39	120.4	.381	.1140	2.458	1.003	.7901	5.250	2/3/16	4/5/16	62	62	1738	6,060,000	452,800	3760	1,477,000	3555	2.05	3730	.263	8996-3
Av.							2.471			5.320					2112			4090	1,786,000	3597	1.75	4050	.269	Av.
8997-1	19'-8"	12.38	12.02	113.4	.251	.0495	1.098	.625	.3067	2.162	12/22/15	2/22/16	62	65	2002	4,377,000†	291,000	2570	1,895,000	2450	1.21	——	——	8997-1
8997-2	"	12.39	12.01	113.1	.250	.0491	1.091	.630	.3117	2.201	1/6/16	3/9/16	63	65	1502	2,780,000	278,100	2460	1,369,000	1750	1.16	——	——	8997-2
8997-3	"	12.31	12.05	114.0	.252	.0499	1.100	.621	.3029	2.124	1/28/16	3/29/16	61	62	1572	3,670,000	267,000	2340	1,905,000	1965	1.25	2350	.318	8997-3
Av.							1.096			2.162					1699			2442	1,723,000	2055	1.21	2350	.318	Av.
8998-1	19'-8"	12.34	12.05	114.0	.250	.0491	1.086	1.000	.7854	5.510	12/11/15	2/5/16	56	59	2402	5,265,000	434200	3810	1,458,000	——	——	3770	.293	8998-1
8998-2	"	12.35	12.00	113.0	.252	.0499	1.109	1.003	.7901	5.592	1/11/16	3/15/16	64	62	1472	5,800,000	383500	3395	1,872,000	2875	1.95	——	——	8998-2
8998-3	"	12.28	12.00	113.0	.256	.0518	1.153	1.002	.7885	5.582	2/1/16	4/1/16	60	60	1830	4,940,000	392,600	3470	1,750,000	2000	1.09	——	——	8998-3
Av.							1.116			5.562					1901			3558	1,693,000	2437	1.52	3770	.293	Av.
8999-1	19'-8"	12.59	12.11	115.2	.383	.1150	2.534	1.000	.7854	5.450	12/17/15	2/12/16	57	59	1965	4,343,000†	440,200	3820	1,758,000	3820	1.94	——	——	8999-1
8999-2	"	12.44	12.31	119.0	.374	.1099	2.383	1.001	.7870	5.290	1/14/16	3/18/16	64	64	2105	6,150,000	437,100	3680	1,990,000	3500	1.66	——	——	8999-2
8999-3	"	12.47	12.23	117.5	.380	.1134	2.470	1.001	.7870	5.359	2/4/16	4/6/16	62	61	1792	5,715,000	384,500	3280	——	3240	1.81	——	——	8999-3
Av.							2.462			5.366					1954			3593	1,874,000	3520	1.80			Av.
9001-1	5'-0"	12.38	——	120.3	NONE						2/18/16	4/15/16	57	57	1055 ‡	2,942,000	133,200	1110 ‡	1,150,000					9001-1
9001-2	"	12.36	——	120.0							3/17/16	5/18/16	62	69	2172	• 3,570,000	206,500	1723	1,325,000					9001-2
9001-3	"										3/24/16	5/26/16	63	62	2060	• 4,000,000	222,200	1858	2,600,000					9001-3
Av.															2116			1790	1,692,000					Av.
9002-1	10'-0"	12.29	——	118.6	NONE						2/18/16	4/15/16	57	57	2062	4,000,000†	201,000	1695	1,430,000					9002-1
9002-2	"	12.33	——	119.3							3/21/16	5/20/16	60	65	2112	• 2,985,000	175,000	1475	1,540,000					9002-2
9002-3	"										3/28/16	5/26/16	59	60	1951	• 3,800,000	192,200	1605	1,900,000					9002-3
Av.															2042			1592	1,623,000					Av.

† Average of 2 Tests. * Not Maximum Load. ‡ Not included in Average. • Average of 3 tests.

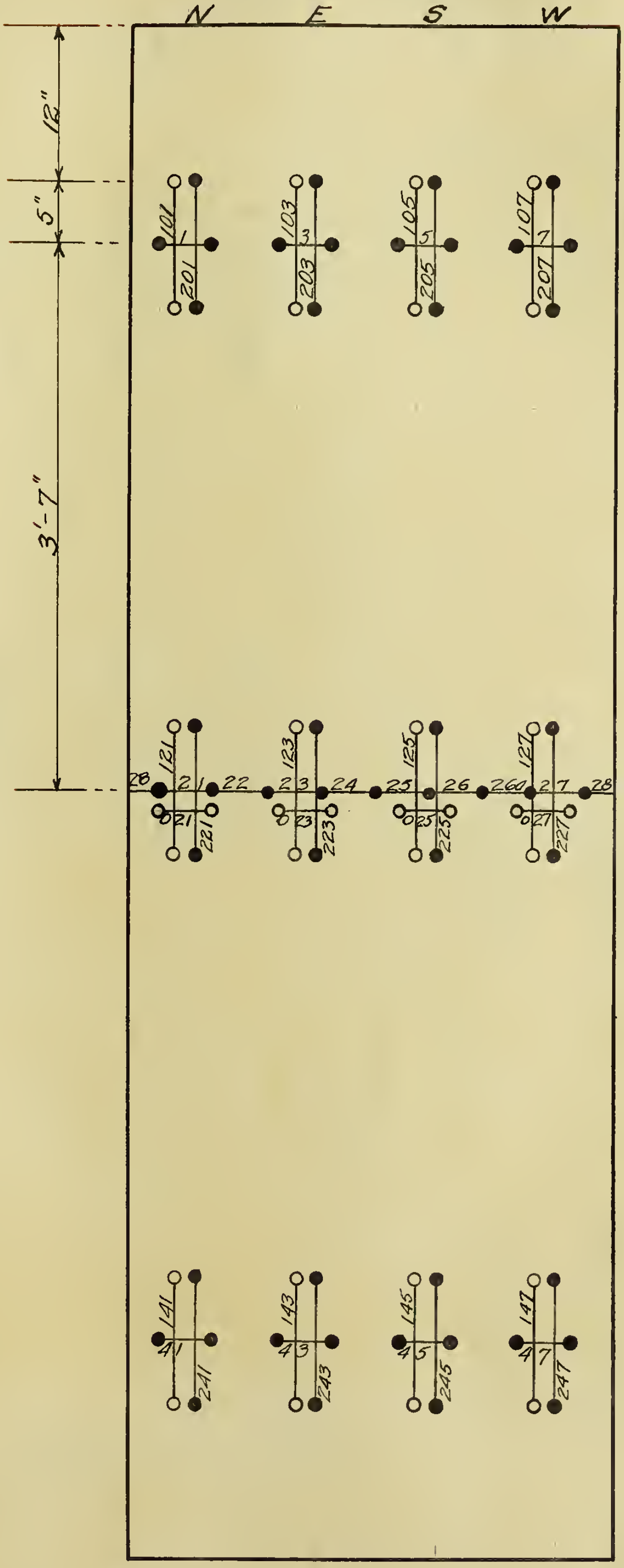
av 1818

LOCATION OF GAGE LINES
ON
5-FT. COLUMNS



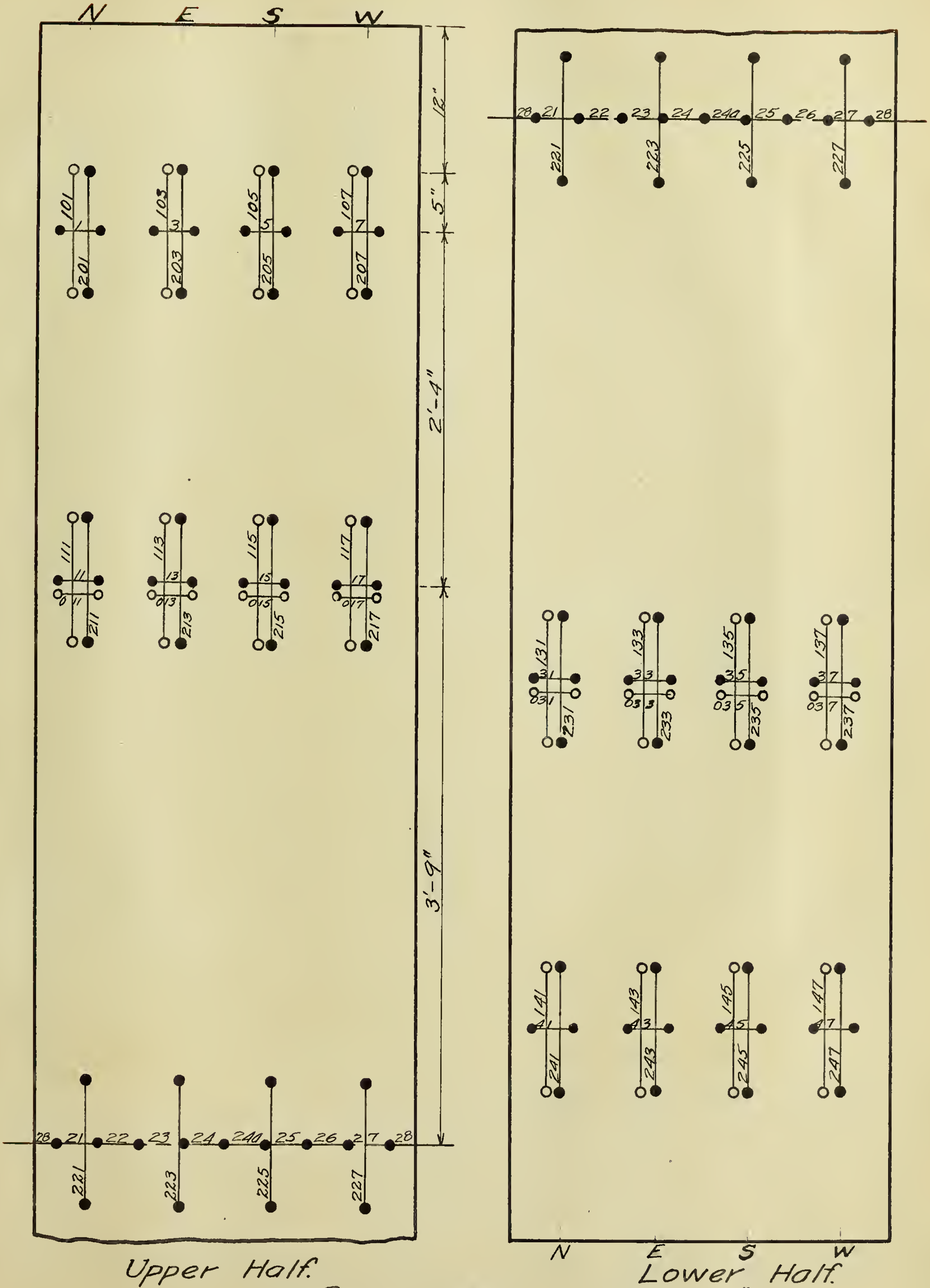
● Gage lines on Steel – 4" & 10"
○ Gage lines on Concrete – 4" & 10"

LOCATION OF GAGE LINES ON 10 FT. COLUMNS



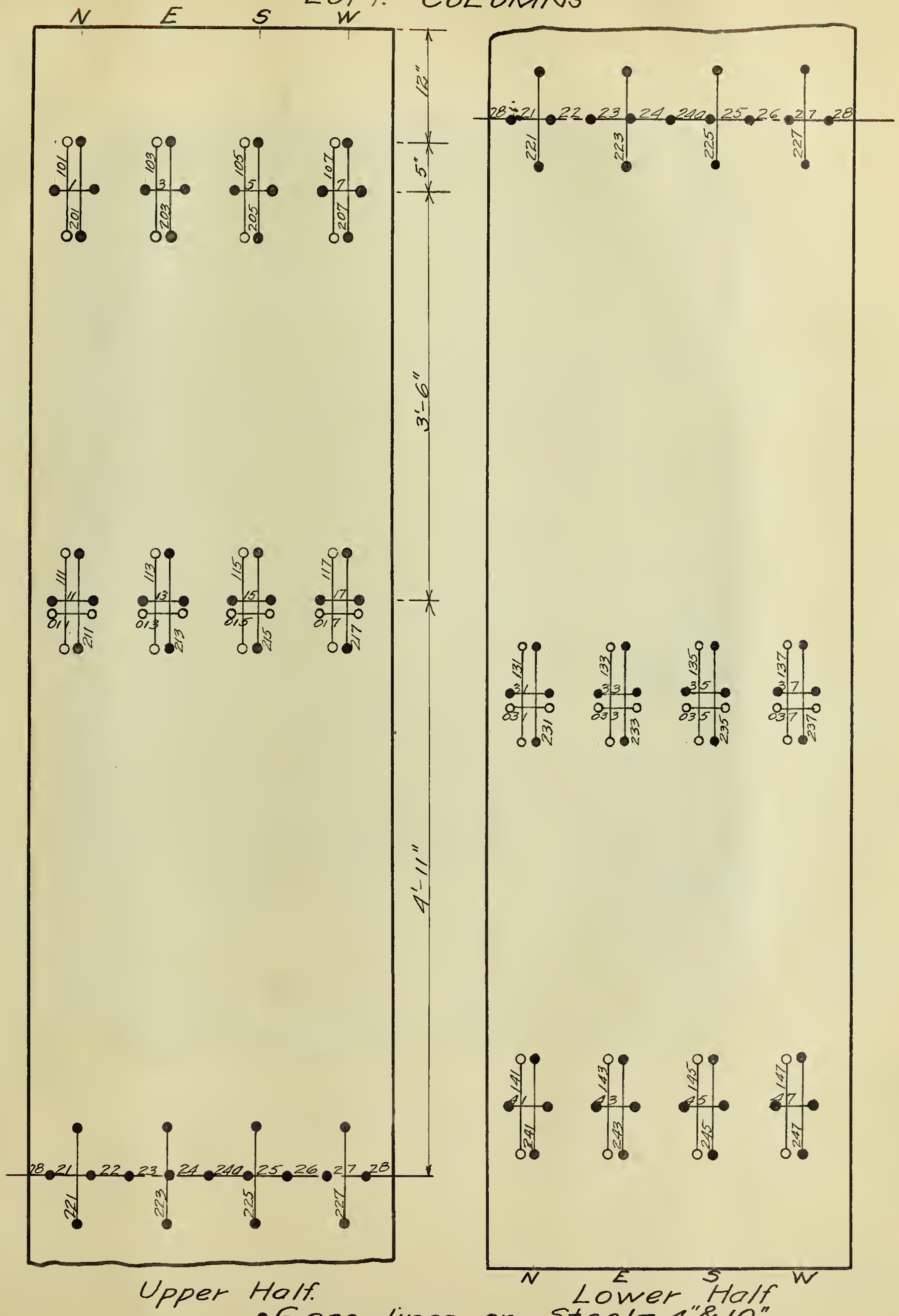
● Gage lines on Steel - 4" & 10"
○ Gage lines on Concrete - 4" & 10"

LOCATION OF GAGE LINES ON 15-FT. COLUMNS

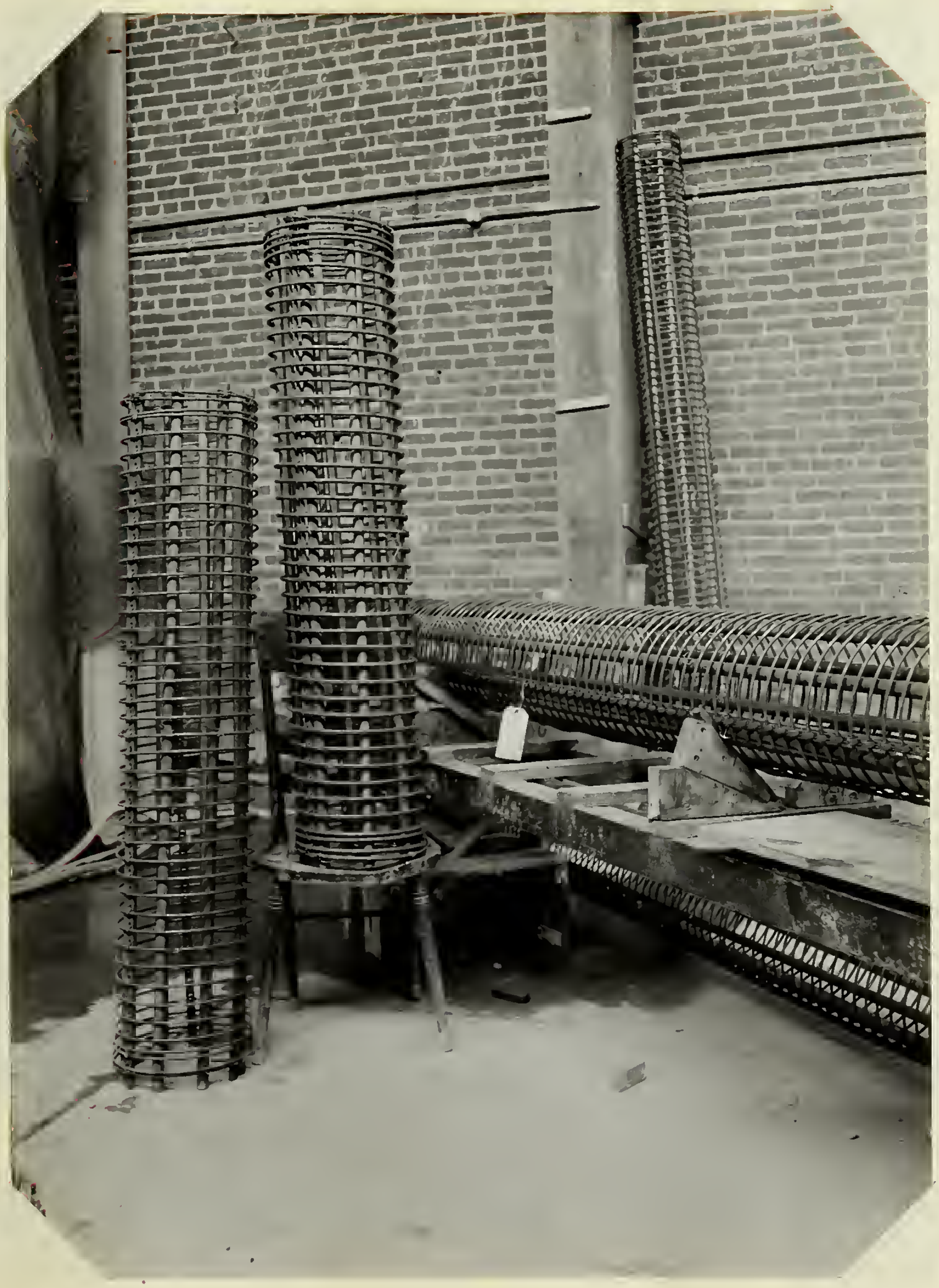


● Gage lines on Steel - 4" & 10"
○ Gage lines on Concrete - 4" & 10"

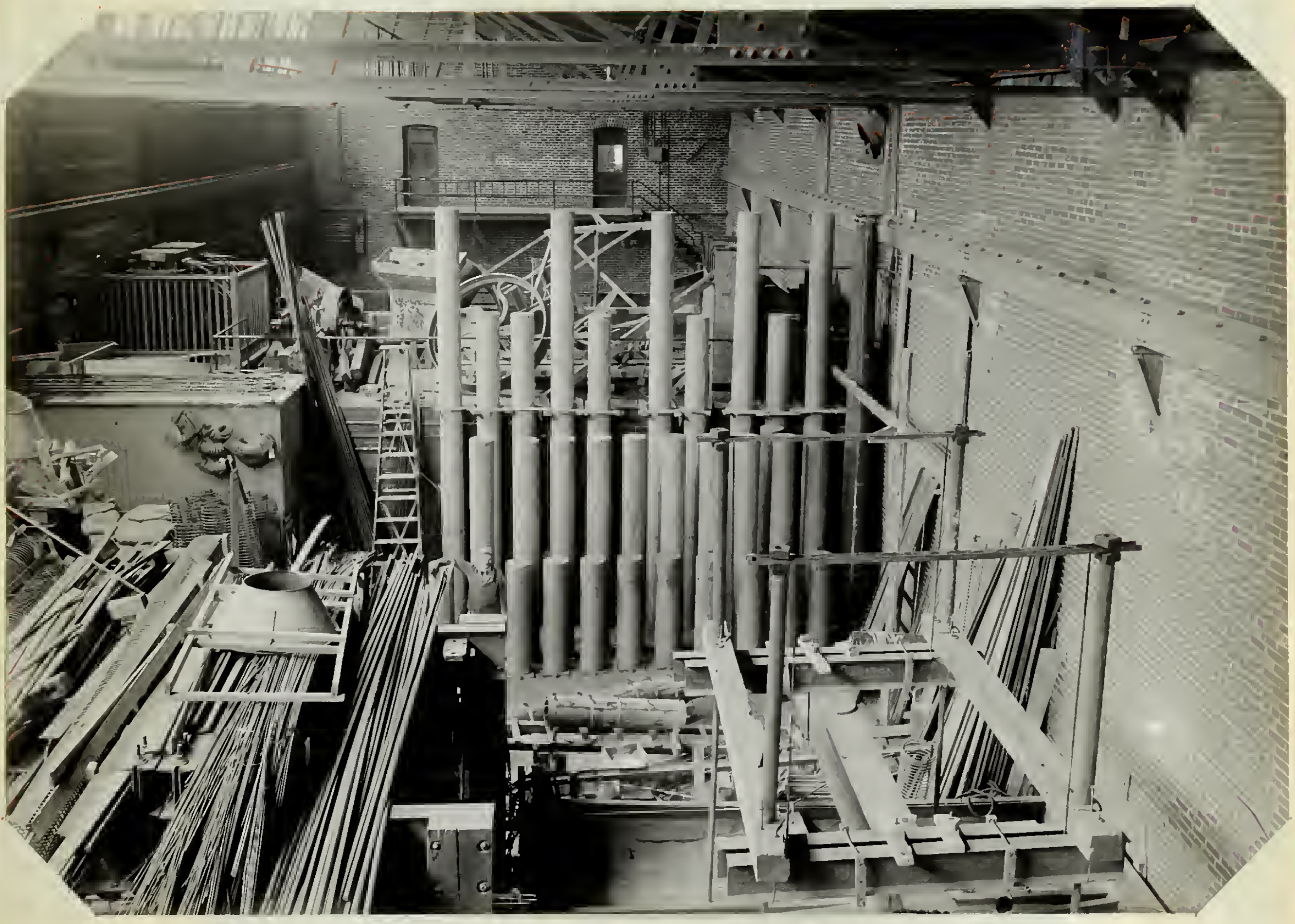
LOCATION OF GAGE LINES ON 20 FT. COLUMNS



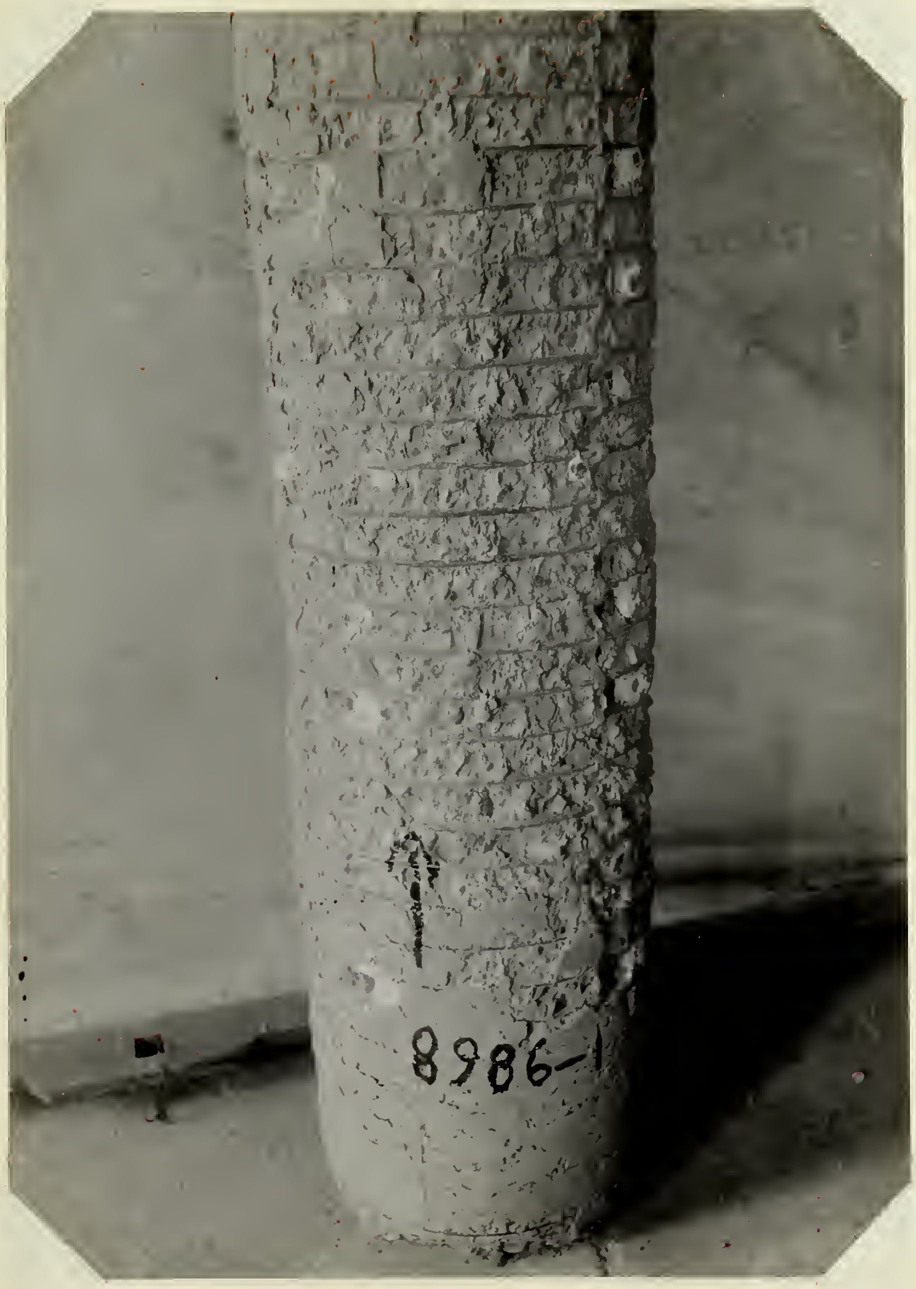
● Gage lines on Steel – 4" & 10"
○ Gage lines on Concrete – 4" & 10"



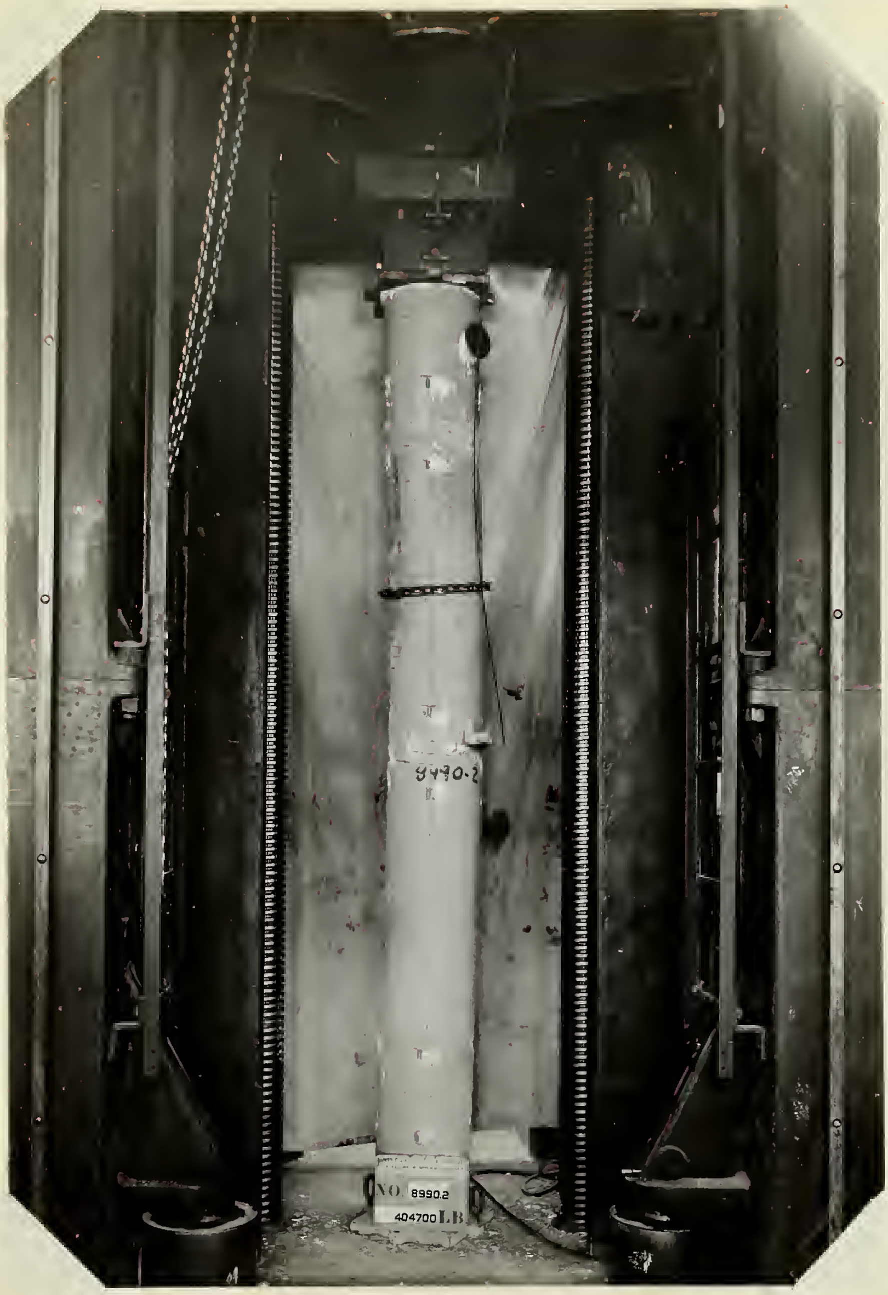
View of Assembled Reinforcement.



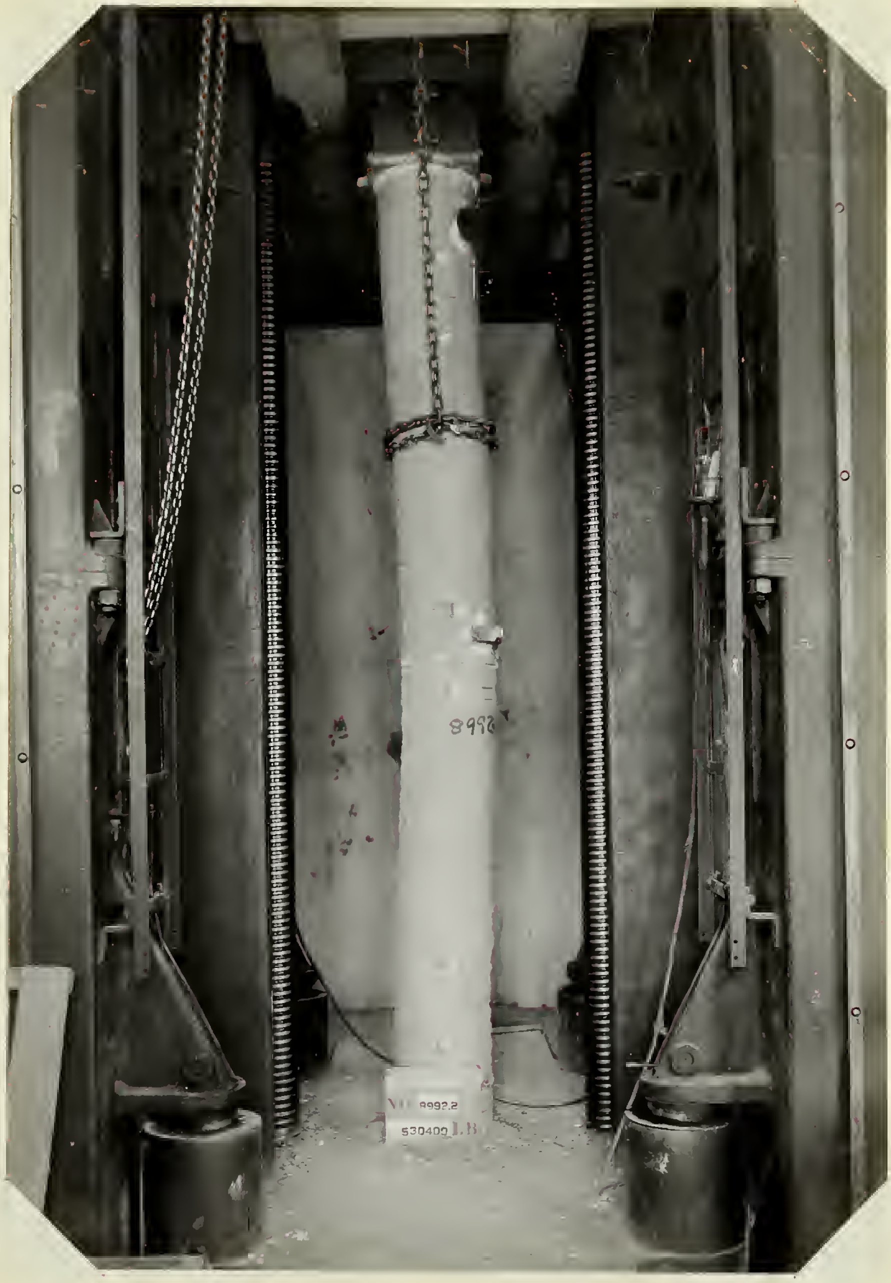
Method of Storing columns, burlap housing removed. The form has not been removed from the 20ft. column at the extreme right.



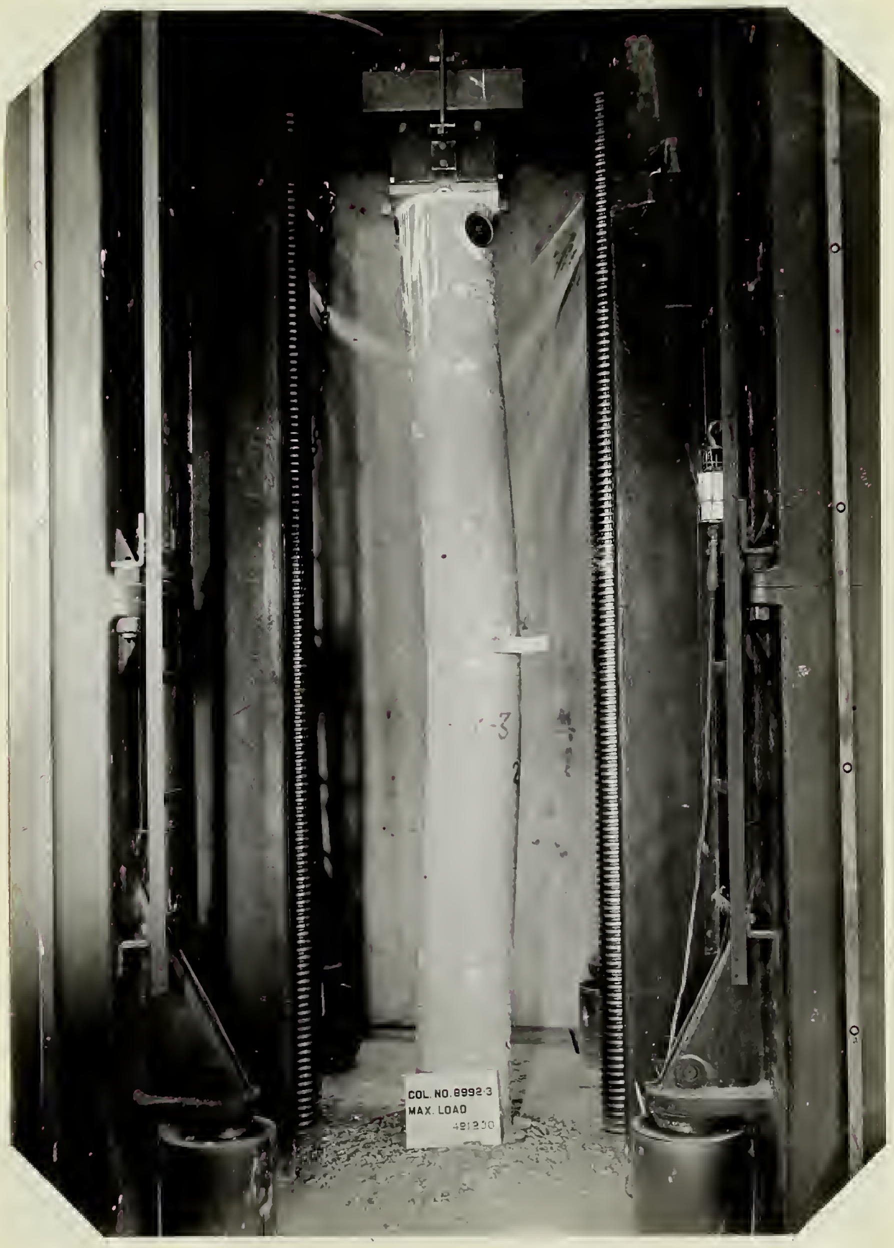
Column 8986-1. Condition of column at end of test. Note the broken spiral at the head of the arrow. Spiral broke at a load of 445,000 lbs. which is equal to 3,790 lbs. per sq. in. on [illegible]



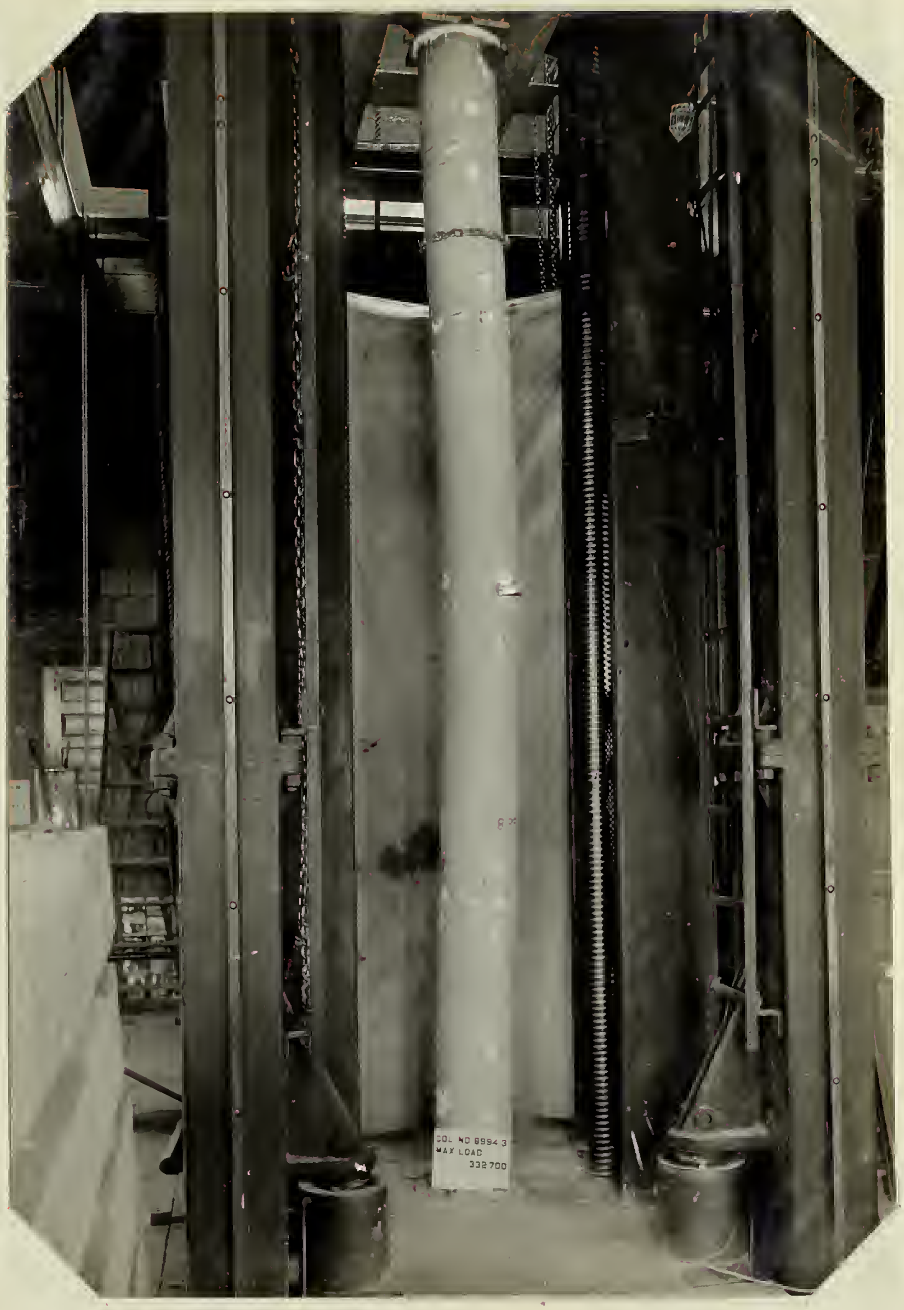
Column 8990-2. Condition at the end of the test. Note the angle blocks and wedges to fix the spherical bearing block and make the column fixed ended.



Column 8992-2. Condition at maximum load.



Column 8992-3. Condition at maximum load. Note deflection apparatus and the condition of fixity of the ends of the column.



Column 8994-3. Condition at maximum load. The deflection at maximum load was 2.00in. to the north and 0.81in. to the west.

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